DOCUMENT RESUME

ED 023 773 24 UD 007 517

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An Automated Primary-Grade Reading and Arithmetic Curriculum for Culturally Deprived Children. Final Report.

Stanford Univ., Calif.
Spons Agency-Office of Education (DHEW), Washington, D.C. Bureau of Research.
Bureau No-BR-5-0684
Pub Date Aug 68
Contract-OEC-5-10-050
Note-211p.
EDRS Price MF-$1.00 HC-$10.65
Descriptors-Academic Performance, *Arithmetic Curriculum, College School Cooperation, *Computer Assisted Instruction, Computers, Data Analysis, *Disadvantaged Youth, Experimental Programs, *Individualized Curriculum, Negro Students, Primary Grades, Programed Instruction, *Reading Programs
Identifiers-California, East Palo Alto, IBM 1500 1800 CAI, Stanford Brentwood Project

This project's main objective in developing and implementing a computer-assisted instruction laboratory program in mathematics and initial reading was to individualize instruction so that each child could progress at his own pace through a subset of materials best suited to his aptitudes and abilities. This theory of instruction attempts to optimize the learning situation by manipulating such variables as the content, nature, and sequence of presentation. Minority-group students (approximately 80 percent Negro) received various combinations of the instruction from 1966 to 1968. During 1965-66 members of the project staff prepared parents and teachers for the technological innovation. The problems in putting the system into operation and the methods by which the students were introduced to the laboratory and its materials are described. It is felt that although much data remain to be analyzed, the findings of this project can serve as a basis of a theory of individualized instruction which would span the diversity and skills found in learning elementary school subjects. (EF)

BR-5-0684
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FINAL REPORT

Project No. H-130

Contract No. OE 5-10-050

AN AUTOMATED PRIMARY-GRADE READING AND ARITHMETIC CURRICULUM FOR CULTURALLY DEPRIVED CHILDREN

ED023773

UD007517

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U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

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An Automated Primary-Grade Reading and Arithmetic Curriculum for Culturally Deprived Children

Richard C. Atkinson and Patrick Suppes

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Summary

The main objective in developing a computer-assisted instruction program in mathematics and initial reading was to individualize instruction so that each child could progress through a subset of materials best suited to his particular aptitudes and abilities at his own pace. For the first time a school-based laboratory was established to conduct curriculum research and to evaluate under controlled conditions the acquisition and retention processes involved in mastering reading and arithmetical skills.

The theory of instruction developed at Brentwood through experimentation with the mathematics and reading programs can, with proper constraints, be generalized to other programs, such as elementary science and beginning work in foreign languages. This theory of instruction attempts to optimize the learning situation by manipulating variables such as content, nature and sequence of presentation, to provide the best learning environment for each individual child. To achieve individualization, a means for determining the best future program of instruction for each child based on the history of his past responses was required. Thus, presentation of materials for each child was controlled by correctness of his past responses, the length of time he took to make them, and the nature of his past learning patterns.

Although much data remain to be analyzed, the work done can serve as the basis of a theory of individualized instruction to span the diversity of concepts and skills found in elementary-school subjects such as mathematics and reading.

Chapter 1

Introduction

The objective of this project was to develop and implement a computer-assisted instruction (CAI) program in elementary-school mathematics and initial reading. Professor Suppes was responsible for developing the mathematics curriculum and Professor Atkinson was responsible for developing the initial reading. At the beginning of the project, lesson materials for neither mathematics nor reading suitable for CAI presentation was available, and an integrated tutorial CAI system had not yet been designed and produced by a single manufacturer. The development of the curricula and the development of the system have been carried on as parallel efforts over the past four years, each having a decided influence on the other.

Before describing this project, a few general remarks about computer-assisted instruction and CAI systems are in order. Three levels of computer-assisted instruction may be defined (Suppes, 1966).[1] Discrimination between levels is based primarily on the complexity and sophistication of the student-system interaction and not on hardware and software considerations. The most advanced student-system interaction may be achieved with a simple teletype terminal, and the most primitive interaction may require some highly complex programming.

At the basic interaction level are those systems which present a fixed, linear sequence of problems. Student errors may be corrected in a variety of ways (e.g., a prompt response may be given in the form of a partial answer, or the entire correct response may be furnished following an error), but no real-time decisions are made for introducing unique teaching strategies or instructional materials on the basis of a student response. Such systems have been termed "drill-and-practice" systems and are exemplified by the Stanford Drill-and-Practice Program in Arithmetic and in Spelling.

At the other extreme of the interaction scale are "dialogue" programs of the type under investigation at Bolt, Beranek and Newman, Inc., and at Stanford University. The goal of the dialogue approach is to provide the richest possible student-system interaction where the student is free to construct unrestricted natural-language responses, ask questions, and, in general, exercise almost complete control over the sequence of learning events.

"Tutorial" programs lie between the above extremes of student-system interaction. Tutorial programs have the capability for real-time decision-making and instructional branching, contingent on a single response or on some subset of a student's response history. Such programs allow the students to follow separate and diverse pathways through the curriculum based on their individual performance patterns. The probability is high in a tutorial program that no two students will encounter exactly the same sequence of lesson materials. Student responses, however, are somewhat limited, since they must be chosen

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[1] Suppes, P. The uses of computers in education. Scientific American, 1966, 215, 207-220.

from a prescribed set of responses or must be constructed in such a manner that relatively simple text analysis will be sufficient for their evaluation. The Stanford CAI Program in Elementary-school Mathematics and Initial Reading is tutorial in nature.

1.1. CAI as a Tool for Teaching

Computer-assisted instruction has a theoretical basis, as indeed does all programmed learning, in the notion that immediate reinforcement facilitates learning. For the human learner, reinforcement may come through verbal praise acting as a reward or through simple knowledge of the results of one's own actions. The Stanford CAI Program provides immediate feedback through reward messages, through the presentation of the next problem, or through wrong-answer messages.

The criticism most often heard about computer-assisted instruction is that the instructional process will somehow become dehumanized, that the students will become little automatons themselves. As it turns out, however, the elimination of the social intercourse aspect of learning through CAI is one of its great strengths. The computer is an eternally patient teacher. The machine never becomes angry or threatening. Those of us who have spent some years teaching in the classroom are well aware of the fact that after repeated student errors it is difficult, if not impossible, to restrain certain voice or facial cues which indicate our displeasure. The messages coming from the machine, however, are completely free of any such threat or anger. The wrong-answer messages recorded in the quiet of the recording studio can be a continuously neutral "No, this is the right word. Touch it."

We have found that attention of even very young students can be maintained at a high level by appropriate pacing of the material and by use of partitions between the response terminals. Thus, the individual student is not distracted by the actions of his classmates, nor is he carried along by their responses. Each individual is responsible independently for interacting with the learning materials.

The basic rationale, however, for the use of a computer-assisted instructional system as a teaching device is the system's potential for individualizing instruction. Intensive investigation in education conducted during the last 60 years indicates that a wide range of individual differences will be found in any classroom on any dimension one wishes to examine. CAI offers us a tool for tailoring our instructional procedures to these individual differences.

The current paper-and-pencil programs can accommodate individual differences in learning time. A bright student who responds rapidly can complete many more frames and cover a greater amount of material in a given time interval than can the slow student who responds quite deliberately. With the nearly unlimited branching capability inherent in a CAI system, students may not only proceed independently in terms of speed, but they are also permitted to follow essentially different paths through the curriculum. Branching decisions for each student in a CAI system is contingent upon a single response, his past history of responses, response latency, or some combination of these considerations weighted by previously acquired psychometric data.

1.2. CAI as a Tool for Research

The usefulness of CAI as a tool for research resides in two factors: (a) the control of independent variables; and (b) the detailed response data which are recorded by the system.

Educational research conducted outside the laboratory in an actual school situation has long been plagued by the impossibility of controlling many variables inherent in classroom organization and in presentation of materials by the classroom teacher. CAI, in a sense, brings the laboratory into the school. Our own CAI laboratory has achieved a degree of environmental control and presentation that has been heretofore impossible in a classroom setting. The temperature and the lighting in the terminal room are constant. The immediate environment of each student's response terminal is precisely the same as every other student's. The chairs and the machines are identical for all students. Every picture seen in the projection device, every bit of orthography or other display on the scope, and every audio message, which the student hears, have been previously specified and can be as standardized or varied as the experimenter desires. This is not to say, of course, that all sources of variation are controlled. The CAI facility does achieve, however, a degree of control equivalent to that of the psychologist's learning research laboratory. Many problems in learning theory, which have been investigated rigorously only in a laboratory setting, can now be looked at in an on-going school context.

The second capability of CAI, which is extremely important for research, is the collection of fine-grained response data. For example, in the Stanford-Brentwood CAI Laboratory, each student response is recorded on data tapes. Each response record includes a complete description of the response in terms of coordinates taken from the face of the scope or the keys depressed on the typewriter. The response is defined as correct or incorrect; and if incorrect, it is categorized according to the type of error made. The response latency is recorded in tenths of a second. The contents of 31 counters and 32 switches associated with the student's past history of performance are also recorded with each response on the data tape.

Another important use of CAI as a research tool is found in the area of mathematical psychology, particularly in the area of mathematical learning models. The quantity and nature of the response data which may be gathered in the CAI system allow the mathematical psychologist to test various models in a situation that is a much closer approximation to actual classroom learning than has existed in the past. Typically, such models have been tested through infra-organism behavior or through such contrived tasks as paired-associate list learning or probability learning. The kind of sequential response data gathered at the Brentwood facility will be used in the development of optimization models for learning (Groen and Atkinson (1966)[1]; Atkinson and Shiffrin (1967)[2]).

1.3. CAI as a Tool for Curriculum Evaluation

Curriculum evaluation is another function of CAI in the educational process. Our current methods of evaluation are extremely gross, relying on standardized tests or specially devised tests given on an intermittent schedule. The best that can be expected from such evaluation procedures is to be able to compare the general outcomes of one method or one curriculum approach to some other method or approach. Little or nothing can be said about the efficiency of any specific section of the curriculum. It is exactly at this detailed level that CAI exhibits its greatest power for evaluation. The performance data gathered in the CAI system may be examined at all levels, from the perspective of overall goals, or from the perspective of the various strategies and approaches adopted in the curriculum. Responses to blocks of homogeneous problem types, responses to separate problem types, and responses to the individual problems themselves also may be examined. At each level we can look at the students' performance records to discover if a particular section, level, or item of the curriculum is functioning in the manner for which it was designed.

[1] Groen, G., & Atkinson, R. C. Models for optimizing the learning process, Psychol. Bull., 1966, 66, 309-320.

[2] Atkinson, R. C., & Shiffrin, R. M. Human memory: a proposed system and its control processes. Technical Report No. 110. Stanford University, Institute for Mathematical Studies in the Social Sciences, March 21, 1967.

Chapter 2

Methods

2.1. The Population

The Brentwood School, a K-6 elementary school with over 800 students, is located in the Ravenswood City School District in East Palo Alto, an unincorporated section of San Mateo County adjacent to the City of Palo Alto. The population of the Brentwood School is approximately 80 per cent Negro with the remaining 20 per cent about evenly divided between Mexican-American, Oriental-American, and Caucasian. The school qualifies for federal aid to impoverished areas under Title I.

During the school years 1966-67 and 1967-68, the Stanford CAI Project worked with first and second graders, as well as with some kindergarten children and fourth graders. The Brentwood School uses a non-graded program based on a level system. In 1966-67, there were four first-grade classrooms at Brentwood, two of which (49 students) received instruction in mathematics under computer control and two of which (56 students) received computer instruction in initial reading. All first graders were included in the program. During 1967-68, 72 children in four second-grade classrooms received computer-assisted instruction in mathematics and 80 children in four first-grade classrooms received CAI instruction in reading. Thus, half of the second graders continued computer-assisted instruction in mathematics for a second year.

2.2. Stanford-Ravenswood School District Cooperative Plans and Teacher In-Service Training

A serious and concerted effort was made by staff members of the Stanford Project to prepare the teachers and parents of the Ravenswood School District, and of the Brentwood School in particular, for acceptance of the technological innovation of a computer-assisted instructional laboratory during the school year 1965-66.

In the early spring of 1965, members of the Stanford CAI Project contacted the local school district, which was selected for the installation of the CAI system. This meeting consisted of a discussion between two senior project staff members and the superintendent and the associate superintendent of the school district. Meetings at this level continued informally on a monthly basis. The purpose of these meetings was to establish cooperative policies and to focus on the financial and legal commitments of both groups.

In early June, 1965, a second preliminary meeting took place between a senior staff member from Stanford and a large group of school district staff composed of the central administration, all elementary-school principals within the district, and the curriculum supervisory staff. A description of the Stanford CAI efforts was given and precise plans for the establishment of the IBM 1500 CAI system within the elementary school were outlined. This group voted to approve the project. Next, the senior staff member from Stanford presented the proposed plans to the Board of Education. In July, 1965, the Board of Education formally approved an agreement which called for mutual cooperation for the CAI Project.

During this time an appropriate school was selected for the CAI Project. The criteria for selection were:

1. a school with sufficient student population to provide at least 120, and preferably 150, first-grade students who could participate in the project;

2. a school whose physical grounds were sufficient to permit the erection of a 30' x 100' building which could become an integral part of the school plan;

3. a school whose student population was predominantly composed of culturally disadvantaged children; and

4. a school whose building principal and faculty had demonstrated through past performance a willingness to undertake new educational innovations.

After the school was selected, a tour of the Stanford CAI Laboratory was arranged for the building principal and five of the faculty members. This tour was followed by a two-hour conference arranged to explain the project to the school staff, and tentative plans were made for further interaction between Stanford and the School District in order to best prepare both groups for this major technological innovation.

With the beginning of the 1965-66 school year, a cooperative plan, formulated by the school liaison member representing the Stanford Project and the principal of the elementary school, was arranged to hold one faculty meeting each month to orient the total faculty about the nature of the CAI Project. This in-service training program served to develop a better understanding of the nature of computer-assisted instruction with its capacities and limitations, of the technology of computers, of the new roles possible for the classroom teacher, and of the development of new curricular content and pedagogical procedures for a more effective school operation. These presentations were made by the Stanford Project staff.

Seven meetings were held during the fall and winter between the elementary-school faculty and the Stanford staff. In addition to the elementary-school faculty, the associate superintendent of the district, central office personnel, and visitors were in attendence at the meetings. The seven presentations given in this period included:

1. an introduction and overview of computer-assisted instruction, the present use of the Stanford CAI Laboratory, tentative plans for the elementary-school CAI project, including the new building and new instructional procedures;

2. terminology of computer-assisted instruction and programmed instruction, a diagram of the CAI system configuration, and a discussion of its possible use in the current elementary-school educational program;

3. the nature of programmed instruction, the preparation of objectives, the need for new curriculum organization and its relation to learning theory;

4. an overview and critical evaluation of several available programmed texts prepared both commercially and by the school staff;

5. the sociology of educational change, the creation of new roles, the function of professional educators and their interrelation with new technology;

6. a series of proposed reading experiments indicating how the CAI system would be utilized for experimentation, and the nature and function of educational experimentation;

7. a report to appropriate sub-groups of the experimental results and how they were analyzed and interpreted.

All of these meetings were organized informally so that extensive discussion between the project staff and the faculty members were both encouraged and pursued in depth.

The project, in cooperation with the San Jose State College Extension Division, offered a two-semester unit course in the spring of 1966. This special studies course, "Computer-assisted Instructional Systems, (Educational Innovations)" met 15 times for a two-hour period and was instructed by Dr. Duncan Hansen and guest lecturers. The professional educators enrolled included 14 faculty members from the selected elementary school (the principal, vice-principal, 2 kindergarten teachers, 7 primary-grade teachers, and 3 intermediate-grade teachers), 18 other members from the school district (the associate superintendent, 2 principals, 3 curriculum consultants, 4 remedial-reading teachers, 3 primary-grade teachers, 3 intermediate-grade teachers, and 2 junior-high school teachers), and 5 teachers from outside the school district representing 3 different school systems.

A more specific program of in-service training was initiated for intensive explanation and questioning of the Stanford Project's mathematics and reading curricula. The mathematics curriculum was presented during lunch-time meetings by Mrs. Jamesine Friend to the school principal and first-grade teachers whose classes were assigned to the mathematics portion of the project. The reading curriculum was presented during seven release-time meetings (i.e., during the school day) by Dr. Duncan Hansen and Dr. Hal Wilson to the school principal, the primary-grade curriculum consultant, the school-guidance counselor, the school-home community worker, and two first-grade teachers whose classes were assigned to the reading portion of the project. These meetings began the intensive interaction between project staff and school-district personnel, which continued throughout the summer with a workshop and into the fall during weekly planning groups.

During the summer of 1966, a two-week workshop was held on the Stanford campus for the two teachers directly involved in the reading program.

A six-week workshop was held during the summer of 1967 in which four teachers from the Brentwood School, Mrs. Joan Brewer, Mrs. Vera Boyson, Mrs. Louise Ahern, and Mrs. Patricia Nordseth, acted as consultants to develop activities which would coordinate their classroom program with that of the CAI Laboratory. During the first half of the workshop, the teachers discussed the types of information needed from the Laboratory to evaluate their students' progress at the terminals. They also discussed the types of activities which would be feasible in coordinating the two teaching programs. The latter half of the workshop was spent in preparing these materials.

Weekly meetings were held between the teachers and the project personnel to evaluate students' progress on the system and to exchange views and information about both the classroom and the laboratory instruction, and the performance of the students in both environments.

A member of the Stanford staff was moved permanently to the Brentwood School, acting as a school-affairs liaison officer. His duties included (a) the resolution of organizational problems that arose in the running of the CAI project within the Brentwood School; and (b) the handling of visitors to the Laboratory.

The preparations and current efforts for school-project cooperation paid off handsomely, and the enthusiasm and support of the teachers was highly gratifying. We have also held many exhibits, open houses, and discussion groups for parents of the Brentwood School and the patrons of the Ravenswood School District. Again, the support of the parents, the school board, the administration and the teachers exceeded all expectations.

2.3. Description of the System

The 1500/1800 CAI system was designed and constructed by IBM engineers in close collaboration with Stanford personnel. The original grant authorized the purchase of the necessary automated teaching units. Leasing of the 1500/1800 CAI system from IBM permitted the Institute for Mathematical Studies in the Social Sciences to refund $144,000 to the Office of Education on March 31, 1967.

The student-response terminals consist of a cathode-ray tube (CRT), a modified typewriter keyboard, a light pen, a film-projection device, and a set of earphones with an attached microphone. The CRT is essentially a television screen on which alphanumeric characters and a limited set of graphics (i.e., simple-line drawings) can be generated under computer control. The film projector is a 16mm rear view filmstrip projector. Still pictures in black and white or color may be displayed under computer control. Each filmstrip, in a self-threading cartridge, contains 1,024 frames which may be accessed randomly by means of a binary code along one edge of the film.

The students receive oral instruction from prerecorded audio messages, which are also randomly accessed. A student response can be entered by use of a light pen, a typewriter keyboard, or an oral response. First, the light pen is a light-sensitive probe which registers a portion of the CRT trace comprising the CRT roster. The precise interval between the initiation of the sweep trace and registry of the trace by the light pen indicates where the light pen has been touched to the screen. This location is stored in computer memory as a set of coordinates that are evaluated by the systems program and compared against predefined coordinates in the lesson program to permit evaluation of a light-pen response as correct, incorrect, or undefined.

Second, responses may also be entered through the keyboard. In order to make the typing response as simple as possible for young children, a special keyboard was designed on which the digits 0, 1, ..., 9 appear in the top row of keys in their correct numeric order (i.e., the 0 is on the left, followed by the 1, then the 2). As the students type, the symbols are displayed on the CRT in whatever position is designated in the coding. No use has been made of this response mode in the reading program.

Third, the children may, when the microphone is activated, record their own production of a given text displayed on the screen which can be played back to them with or without an adult model. The recording and playback capability helps compensate for the absence of a voice analyzer. The system cannot evaluate the student's vocal production and, therefore, each student becomes his own voice analyzer. This mode of response was not used in the first-grade mathematics program.

The 16 student-response terminals are serviced by an IBM 1800 Process Control computer. This central processing unit has a relatively limited (i.e., 32K) immediate-access core storage. Rapid-access bulk storage is provided by six interchangeable disk drives; each disk contains 512,000 16-bit words. The audio component of the system consists of a bank of IBM 1505 audio units. Each audio-drive unit is connected to one of the response terminals, but the connections can be varied at will. Response data flowing into the system from the student terminals are recorded on two IBM 2402 tape units. An IBM 1501 station control, a 1442 card reader punch and a 1443 line printer complete the configuration of the IBM 1500 CAI system as shown in Figure 1.

Insert Figure 1 about here

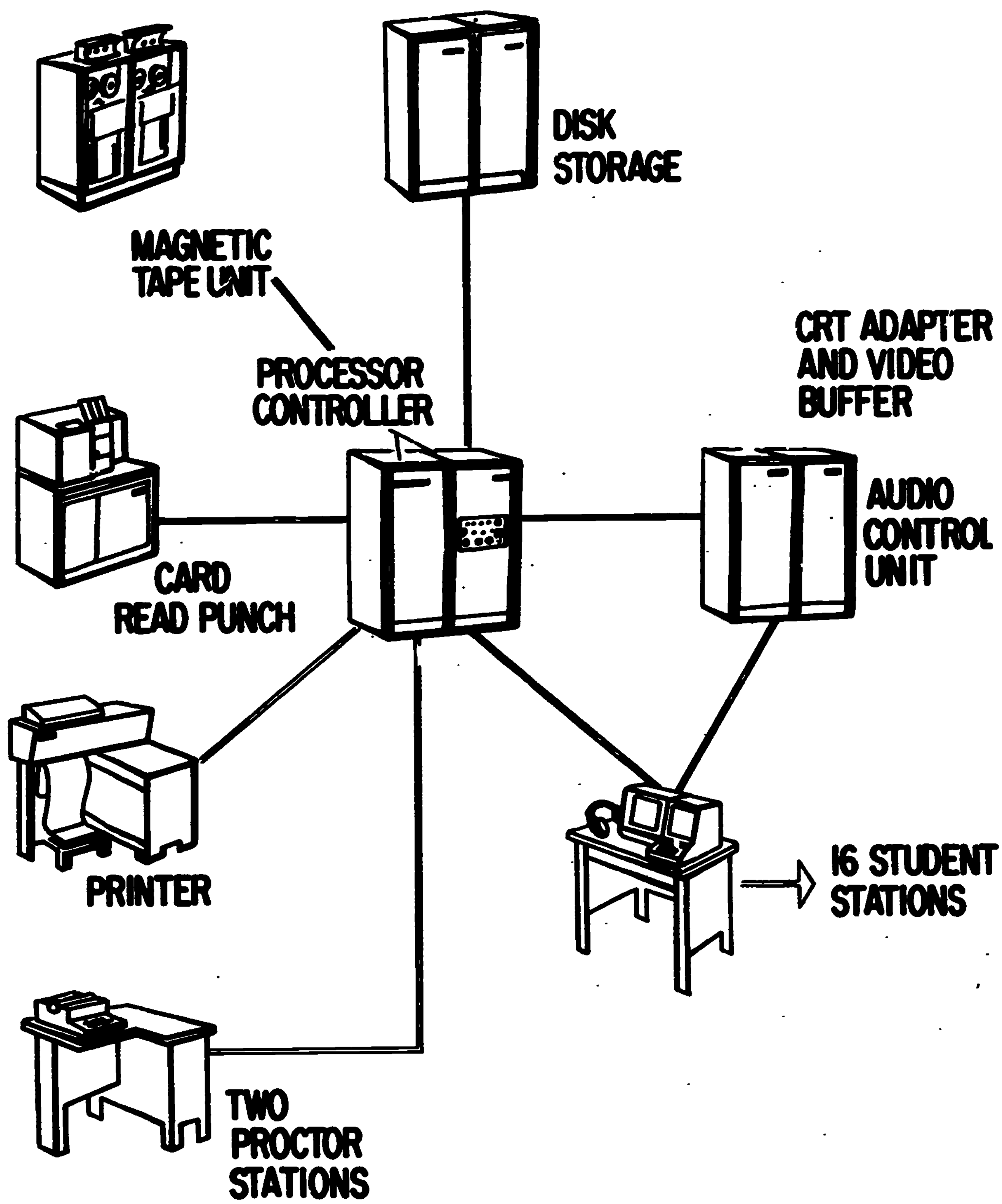

Fig. 1. System Configuration for Stanford-Brentwood CAI Laboratory

The IBM 1500 CAI system is a time-sharing system in the sense that the activities of each student-response terminal are examined in sequence and appropriate action is taken. The time-sharing is not strictly sequential in that an interrupt feature allows certain priority conditions within the instructional system to alter the sequence of programmed instructions.

A nontechnical characterization of the flow of information in the system may serve to suggest the operation of the time-sharing system. Assume that we are breaking into an instructional session and that the system is preparing to examine a response entered by a student at terminal 1. The appropriate terminal record and lesson instructions are read from the disk storage and placed in core. The response coordinates from terminal 1 are evaluated and compared to those stored in the lesson program for the given problem. (See the section on lesson coding for a detailed discussion.) Decisions are made on the basis of the lesson program logic and appropriate commands are given: (a) to the station control to display certain text on the CRT; (b) to the film projector to position and display a certain frame; and (c) to the audio unit to play track α segment n to segment $n + p$. The attention of the system then moves to terminal 2 and the process is repeated.

The above description is almost allegorical in its oversimplification. It is intended only to give a general feeling for what is meant by time-sharing on the system. For a complete technical discussion the reader is referred to CAI Programming Systems Users Guide, Preliminary Draft, IBM, Armonk, New York, 1967.

The entire process moves at a very rapid rate. Subjectively, the student at the terminal feels he has the full attention of the system. The response time for the CRT is less than 1 second, and the projector response is nearly as fast. The audio response time is somewhat slower, ranging from 2 to 4 seconds on the average.

The Laboratory is housed in a rectangular prefabricated steel structure approximately 3,200 square feet in area, located on the Brentwood School grounds. The building contains the terminal room, the off-line teaching room, the central computer room, and a group of offices for the Laboratory personnel.

The staff of the Stanford-Brentwood CAI Laboratory consists of 10 members. The Laboratory is under the general management of a senior programmer, who is also in charge of the data reduction staff. His staff includes two programmers, two graduate students and a secretary, who also serves as a receptionist. The systems group is headed by a second senior programmer, who has on his staff an assistant programmer and a computer operator, plus a technician who handles audio assemblies. The coding groups for both the mathematics and the reading programs are also housed in the Laboratory. The reading coding group is directed by a senior lesson programmer and consists of four coders, plus part-time debuggers and graduate assistants. A similar number of personnel constitute the mathematics coding group. Proctors handle the children in the terminal room itself and are responsible for off-line instruction. IBM has also provided several customer engineers, who are either on duty at the Laboratory or are on call. At present, the stability of the system is such that IBM customer engineers have been reduced to a single man during school hours.

2.4. Laboratory Operation 1966-67

Full-scale operation with the students began on November 1, 1966. The daily schedule is indicated in Table 1. The starting date was

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Insert Table 1 about here

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somewhat later than originally anticipated, because of a delay in the delivery of the 1500 system, which arrived at the Brentwood School on July 10. The interval from July 10 to November 1 was devoted to a shakedown and debugging of the system, which was, of course, untested in on-line operation.

Mathematics. On October 3, 49 children from two of the first-grade classes at Brentwood School went to the CAI classroom. Each class was divided into two groups of 10 to 14 children; each group was in the Laboratory for 25 minutes on Monday through Friday afternoons between 12:30 and 2:30 p.m. (See Table 1.)

Until October 27, the groups' activities were limited almost entirely to the classroom which was supervised by two credentialed teachers working sometimes as a team and sometimes separately. During the week of October 3, preliminary counting tests were given to each child. It was found that 11 children had inadequate counting skills. They were tutored individually throughout the month of October.

On October 4, 5, 10, and 11, half of each group spent classroom time on the playground with a psychologist, Dr. Rivka Eifermann of the Hebrew University, Jerusalem, Israel, who taught them simple games incorporating the concept of sets, including the empty set. Later in the week, all children were asked the same series of questions about sets to determine whether those who had played the game had a better understanding of what a set was. The results were not conclusive.

During the week of October 21, 5 children from each group were taken out of the classroom each day for individual testing. The tests which were designed by the School Mathematics Study Group were administered by CAI staff, and results were compared with those obtained by the School Mathematics Study Group in its study of culturally disadvantaged children.[1]

[1] Leiderman, G. F., Chinn, W. G., & Dunkley, M. E. The special curriculum project: Pilot program on mathematics learning of culturally disadvantaged primary school children. School Mathematics Study Group Reports, No. 2, 1966, Stanford University. 132 pp.

TABLE 1

Systems Schedule (November, 1966)

7:00	8:30	9:00	10:00	11:00	11:35	12:00	12:05	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00	7:00
Monday FE IBM			READ Students		SYS			MATH Students		MATH Debug		READ Debug			MATH Debug		PRODUCTION			
Tuesday FE IBM			READ Students		SYS			MATH Students		Math Reports	SYSTEM				READ Debug		PRODUCTION			
Wednesday FE IBM			READ Students		SYS			MATH Students		MATH Debug		READ Debug			MATH Debug		PRODUCTION			
Thursday FE IBM			READ Students		SYS			MATH Students		Math Reports	SYS	READ Debug	SYS		READ Debug		PRODUCTION			
Friday FE IBM			READ Students		SYS			MATH Students		Math Reports				SYSTEM			PRODUCTION			
Saturday											ANALYSIS									
Sunday																		PRODUCTION		

On October 2[illegible], class time for Group IV was divided into two periods of 10 minutes each. Each period half of the group (five children) went into the terminal room for computer-assisted instruction, while the other half remained in the classroom with one of the teachers. In the terminal room, each child was assigned a proctor who helped him get started and monitored the entire lesson which lasted for three to five minutes. All children were faded[1] after the first lesson. On November 1, the children in Groups I, II, and III did the first lesson under the close supervision of a proctor. On that same day the children in Group IV worked for 15 to 17 minutes. The seven proctors did not monitor these children, but merely observed them as they worked. The children were attentive throughout and did not seem to tire of the work. At the end of the 15 minutes, one child had nearly completed Book 1. During this period, however, proctors detected some errors which were especially confusing to children new to machine work. (In one case, an audio tape "ran-away" and played on, independent of the problems being solved. In a few cases, the computer mistakenly identified a correct answer as incorrect.) Because of these errors, it was decided that the children should report to the terminal room in groups of seven or fewer, so that each child could be monitored by one of seven proctors until the error problem was minimized.

On November 7, a regular schedule for children in the terminal room was established. Groups continued to be divided into two 10-minute periods, with a proctor assigned to listen with one child. An additional proctor took care of the proctor typewriter and loaded audio tapes at the beginning of the day or whenever a child transferred from one book to another. The fade command allowed each child to finish the lesson he was working on and return to the classroom before the 10-minute period was over.

By November 9, most children were starting their lessons without help from a proctor. A child would find the CRT displaying his name, sit down, put on his earphones, and start the program by touching the display with his light pen. Those who did not start their program by themselves usually waited for a proctor's go-ahead, not because they did not know how, but because they either wanted attention or were reluctant to begin without an authority's approval.

If a child failed to meet the established criterion for a lesson, his proctor, responding to instructions typed on the proctor typewriter, would assist him, recording all pertinent information on a special sheet to be handed over to the master proctor at the end of the day. Notes from these sheets were used both to inform classroom teachers of each student's progress and to aid revision of the material.

The children quickly learned that a CRT display of words "you have been signed off" meant the end of the day's lessons. Most children put away their earphones and left the terminal room quietly; those who did not were reluctant to leave, or again, wanted attention from the proctor.

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[1]The FADE command, which is input by a proctor, causes a student station to be signed off as soon as the student completes the current lesson.

The above schedule was maintained until December 12, when it was changed for the following reasons:

1. Errors in the programmed lessons had been reduced significantly by a change in coding. Children had also become more familiar with the machine and its eccentricities and were less confused by errors that did occur.

2. A proctor's presence had become harmful to some students; some were embarrassed when they knew an adult was watching them make mistakes; some were becoming reliant on a proctor's assistance and would look to him for approval before making a response; some had come to think of a proctor as an integral part of machine work and would not start without being monitored.

3. The short 10-minute periods made any kind of classroom activity difficult.

4. The short periods were also unsatisfying to those students who had time for only one lesson before they were signed off.

There were several advantages in having a proctor for each child. The proctors could interfere immediately whenever a machine error caused confusion to a student. The students' interaction with the programmed material could be observed closely, and notes which would be invaluable when making revisions could be written in some detail. Also, the proctors could be more effective in assisting a student who had failed criterion for a lesson.

The advantages of individual proctors were overruled by the disadvantages listed above. On December 12, therefore, the previous schedule was changed and only three proctors remained in the terminal room; two proctors provided individual help, while a third supervised the room as a whole and dealt with discipline problems. A fourth proctor's duties included changing audio tapes and dealing with minor systems difficulties. Each child was assigned a permanent station, and the groups were no longer divided into two periods. Seven to 10 children worked on-line for 12 to 15 minutes; fade time was standardized by the clock so that all children returned to the classroom by a specified time. Two to four children remained in the classroom each day on a rotating basis, thus allowing more time and space for valuable classroom instruction and activities. The current schedule has been very satisfactory for both the proctors in the terminal room and the classroom teacher.

Reading. From the opening of school in September to mid-October, the program of pretests, which was begun in the spring, was completed by Dr. Lucille Mlodnosky. The following tests were given:

Short form of the Stanford-Binet Revised Form LM.

Marianne Frostig Developmental Test of Visual Perception.

a) eye-motor coordination

b) figure ground

c) form constancy

d) position in space

e) spatial relations

Bender Gestalt Test. Group Administered, Kopitz Scoring System.

Bender Gestalt Test. Individually Administered, Kopitz Scoring System.

The Sprainge Multiple Choice Bender Gestalt Test. Individually Administered.

Belmont-Birch Test for Awareness of Left-Right Relations.

Peabody Picture Vocabulary Test.

The Illinois Test of Psycholinguistics: Auditory-Vocal Automatic and Visual Motor Sequential Subtests.

On November 1, the students went to the Laboratory on a daily basis. The students received a week of orientation in the off-line teaching room and became acquainted with the use of the earphones, microphone, and light pen. Exercises and games were used to familiarize them with the equipment and the kinds of learning tasks they would encounter in the terminal room. During the second week in November, they were introduced gradually to the actual response terminals on a staggered basis; that is, a lesson in the terminal room was followed by a lesson in the off-line teaching room. By November 15, the students were on the system daily for a 20-minute instructional period. During these early exposures to the terminal equipment, an adult was stationed behind each child to assist him with whatever problems he might find in handling the equipment; however, the children adapted quickly to their new environment, and the adults were gradually withdrawn. By mid-November the proctor staff within the terminal room consisted of one teaching proctor, one machine proctor, and a remedial-reading teacher.

The students went to the Laboratory in four groups, since the terminal room was equipped to accommodate only one half of a normal classroom at a time. Each group received 20 minutes of instruction, and there was a minimum of 10 minutes between groups. The 10-minute interval was necessary to prepare the system for the next group. Each student was signed on at a response terminal, and the appropriate films and audio tapes were loaded into the projectors and audio-drive units. When the sign-on process was complete, the name of the student assigned to a given terminal appeared on the CRT.

When a new group of students arrive at the terminal room they enter, seat themselves before their assigned terminals, put on their earphones, touch their names with the light pen, and the lesson begins. During the instructional session, the machine proctor is stationed at a proctor's typewriter which transmits messages from the central system. These messages consist primarily of identification of some system or terminal failure, transfer of a student from one lesson to the next, or notification of an error limit exceeded at some terminal. In a system or terminal failure, the machine proctor takes appropriate action, which may range from transferring a student to an empty terminal to notifying the head systems programmer. When a student transfers to a new lesson, the machine proctor must change his audio tape. Each block of problems within a lesson has an error limit of 50 per cent of the total number of problems within the block. If this error limit is exceeded by the student, notification of this condition is transmitted to the machine proctor, who in turn conveys the information to the teaching proctor. The teaching proctor then observes the student and chooses between two courses of action. If the difficulty appears to be mechanical (e.g., the student is not using the light pen correctly) or some minor misunderstanding of directions or lapse of attention, the teaching proctor may sign on the terminal with the student and help him through the troublesome section. By signing on the terminal, a proctor bit is set in the response record to identify responses that are not necessarily those of the student. If, however, the student's difficulty appears to be of a serious nature, the proctor may remove the student from the terminal and transfer him to the remedial teacher for diagnosis and personal instruction in the off-line teaching room. Fortunately, during the entire year's run, the necessity for such off-line instruction has been very infrequent. The remedial-reading teacher has functioned primarily as an assistant to the teaching proctor within the terminal room and has been brought into play in her major function only when the system has gone down or an individual terminal has failed.

Both the teaching proctor and the remedial-reading teacher hold elementary teaching certificates from the State of California and are experienced classroom teachers. The machine proctor is a member of the lesson programming group. The children are accompanied from the classroom to the terminal room by an assistant proctor who performs certain clerical tasks while the students are on-line.

Since the two first grades in the reading program are part of the ungraded primary plan at Brentwood, a certain amount of transfer students between the low-and high-maturity rooms took place in the course of the year. The exchange of the students from one group to another was one of the major topics of the weekly meetings between the first-grade teachers and the Brentwood project staff. We were able to accommodate all requests by the teachers for exchanging students within groups. Our only stipulation was that the exchanges be made known to the project staff by Thursday of the week preceding the actual change of students from one group to another. The lead time was necessary to keep the student registry pack in proper order.

The amount of migration of students to and from the Brentwood School has been relatively small. Four of the original students in reading left the school and were replaced by four incoming students.

The population of the first-grade classrooms was somewhat smaller than anticipated, which left terminals unoccupied for each of the four groups. During the early phases of the program, this arrangement was fortuitous in that spare terminals were available for transferring a student when his original terminal failed. After Easter vacation, however, it was felt that the system had achieved a degree of stability, and no longer required a large number of terminals as backups. The empty terminals were then filled with an appropriate number of remedial second-grade students. The second-grade teachers involved reported a definite increase in interest and application to the reading task within the classroom.

2.5. Laboratory Operation 1967-68

Mathematics. On September 18, a staggered-day schedule began in the primary grades, and students reported to the Laboratory for mathematics. Two days were spent testing and establishing routines and schedules, and on September 20, the students started the programmed lessons. The daily schedule for mathematics students is given below.

	No. of Pupils	Math-Lab Class	CAI Instruction
Group 1	13	11:00-11:30 A.M.	12:30-12:55 P.M.
Group 2	17	12:30-12:55 P.M.	12:55-1:20 P.M.
Group 3	13	12:55-1:20 P.M.	1:40-2:05 P.M.
Group 4	14	1:40-2:05 P.M.	2:05-2:30 P.M.
Group 5	14	2:05-2:30 P.M.	2:30-3:00 P.M.

By September 29, after eight days of CAI instruction, the fastest child had completed 5-1/2 books (62 lessons), while the slowest child had completed 2 books (25 lessons).

Reading. On September 18 and 19, 1967, 79 Brentwood first-grade students were introduced to computer-assisted instruction in intial reading. While a remedial teacher worked with the remaining children, two students worked at a student terminal with the light pen and earphones. All the children were familiar with the terminal equipment by September 20, when they began work on Days 1 and 2, the introductory lessons.

Proctoring procedures were modified as the student's individualized introduction to the terminal equipment eliminated the need for adult supervision on a one-to-one basis. Only the head proctor, the machine proctor, and an on-line proctor were present in the terminal room. In addition, a certified remedial teacher was always present in the teaching room for off-line remedial work.

On September 25, the students began Day 3, which consisted of Read I-93 and I-94, the letter-teaching lessons. On September 29, after the first week of instruction, the students were distributed as follows:

Lesson	Number of Students
Day 3	42
I-01	24
I-02	10
I-03	3
	79

Chapter 3

The Curricula

3.1. Mathematics

The four hundred lessons in the first-grade mathematics program covered the ordinary range of first-grade arithmetic topics such as counting, numerals, addition, subtraction, linear measure, as well as a few topics less commonly found in first-grade, namely, sets and set notation, congruence of plane figures. The content and scope of the curriculum were drawn largely from Sets and Numbers, Book 1 by Patrick Suppes[1], with the addition of some topics, such as oral story problems, which cannot by their nature be adapted to a textbook format.

Since the programmed lessons were tutorial, many of the lessons were explanatory, relying on oral explanations synchronized with changing visual displays. The average lesson contained fewer than 10 problems, and explanations were simple and direct. Generally, the problems within one lesson were all of the same type; the first few were accompanied by explanatory audio messages and the remainder were practice problems.

Both explanatory and practice problems contained provisional audio messages which were heard only by students who responded incorrectly or failed to respond within a reasonable time. The function of some different types of audio messages can be illustrated by a detailed examination of a single lesson, Lesson 6GL, "Finding a set with the same number of members."

The initial CRT display for the first problem pictured a car and a truck surrounded by set braces, and was accompanied by the audio message "There are two members in this set." After this message, two more sets appeared below the first set, one empty and one containing a train and a steamshovel. The student heard the instructions "Find another set with two members." At this point, a small "p" was displayed in the corner of the CRT as a signal to the student that the system was ready to receive his light-pen response. As soon as the student chose the correct answer he saw a smiling face, heard "Yes, the sets have the same number of members," and proceeded to the next problem.

For the first problem in Lesson 6GL, the data showed that 44 out of 49 students chose the correct answer. Three students made no response within 20 seconds and heard, "Which set below has two members?" The two students who responded incorrectly saw a sad face and heard the audio message, "Point to the box next to the set with two members." After this negative reinforcement routine, they were given a chance to respond again, and both responded correctly.

For this problem, as for most problems throughout the curriculum, students were allowed three chances to produce the correct answer. After

[1] Suppes, P. Sets and Numbers, Book 1. New York: Singer, 1965.

three incorrect responses, the correct answer (or an arrow pointing to the correct choice) was displayed, accompanied by a brief audio message. Moreover, a time limit of 20 seconds was set for every problem, and when that limit was reached, an additional hint was given. If a student did not respond within 40 seconds, the answer was displayed. In any case, the student was required to make the correct response before the program continued to the next problem.

The second problem in Lesson 6GL was also explanatory. "There are zero members in this set. Find another set with zero members." Similar audio instruction accompanied explanatory problems 3 and 4. Problem 5, preceded by the audio message, "Do the next problems by yourself," was the first in a block of nine practice problems which had no oral instruction.

Lesson 6GL was taken by 49 students with 41 to 46 initial correct responses on the 13 problems. As was to be expected, the most difficult problem was problem 2 (the empty set) with no accompanying oral instruction. The average response time was 6 seconds, and no student failed to respond within the 40-second time limit.

For the practice problems, the last nine problems of the lesson, the number of initial correct responses made by each student was accumulated and compared to a preset criterion. In this lesson, the students were expected to answer 7 of the 9 problems correctly (other possible criteria: 5 out of 6, 6 out of 8, 8 out of 10, etc.). As soon as a student made the required number of correct responses (in this case, 7) he was allowed to skip the remaining problems and to begin the next lesson. On the other hand, if a student missed any three of the nine problems, he was clearly failing criterion and was branched immediately to the remedial lesson, by-passing remaining problems in the lesson. In Lesson 6GL, there were four students who failed to meet the 7 out of 9 criterion. They received immediate remedial material in the form of a lesson containing the same kinds of problems, but with a slower development of the ideas using simpler vocabulary and sentence structure.

Lesson 6GB was the remedial branch for Lesson 6GL and contained 13 problems with a criterion of 6 correct in the last 8 problems. None of the four students who took Lesson 6GB failed to meet the criterion. If one of them had failed, his program would have stopped, and an automatic call for assistance from a proctor would have been typed at the proctor station.

The lessons we have been discussing formed a part of a sequence on comparing the cardinality of sets; Lesson 6GL was aimed more at introducing the format and response mode, as well as the vocabulary of comparison, than it was at providing practice with more difficult discriminations. For this reason the problems were simple, with the number of members of the sets restricted to four or less, and the number of choices was small.

Later in the year as the concepts of counting and addition were assimilated, students were required to give constructed responses using the keyboard. Slightly more than one-fourth of the lessons required typed responses. Regular drills with problems of varying degrees of difficulty were provided. In order to adapt the curriculum to individuals, the drills were usually written on five levels of difficulty with branching decisions based on individual records.

The lessons were grouped in "books" varying in length from 9 to 34 lessons; the length of a book was quite arbitrary, being the amount of manuscript a curriculum writer could comfortably carry. Table 2 shows the number of lessons and problems categorized according to core curriculum, remedial material, and drill for each book.

Insert Table 2 about here

The amount of material contained in remedial branches was a major factor in the rate of students' progress through the curriculum. With the exception of several children who entered school late in the year, all students began programmed instruction in Book 1 on October 27, 1966. Table 3 shows the books in which students were working at the end of the school year.

TABLE 3

Book No.	10	17	18	19	20	21	22	23	24	25
No. of students	1*	7	5	4	12	2	10	3	6	2

*This student received classroom instruction during the latter part of the year.

Content of programmed lessons. A complete outline of the programmed curriculum can be found in Appendix 1. The topics covered include the following:

1. Sets. Concept of a set and member of a set, description of sets by naming a common property, description by enumeration, use of set braces, empty set, equality of sets, union of sets, solving set equations, equivalence of sets, use of N-notation as a pro-numeral, construction of equivalent sets, difference of sets, subsets.

2. Numerals and counting. Numeral recognition, counting objects in arrays, counting randomly arranged objects, counting members of sets using N-notation, successor, predecessor, counting by two's, counting by five's, counting by ten's, counting by ten's and one's, place value, place value related to dimes and pennies, more and less, number line, oral story problems.

TABLE 2

First-Grade Mathematics Programmed Curriculum

	Number of Lessons				Number of Problems			
Book	Core curriculum	Remedial branch	Drills	Totals	Core curriculum	Remedial branch	Drills	Totals
1	8	1	0	9	59	6	0	64
2	10	8	0	18	83	65	0	148
3	8	5	2	15	91	61	34	186
4	11	4	1	16	102	43	10	155
5	7	6	0	13	60	53	0	113
6	16	16	2	34	165	155	21	341
7	10	6	1	17	118	35	11	164
8	4	2	4	10	39	25	40	104
9	6	7	3	16	119	102	30	251
10	8	2	2	12	76	30	20	126
14	8	0	2	10	89	0	20	109
15	5	7	3	15	63	78	30	171
16	8	5	1	14	96	57	10	163
17	17	6	2	25	185	60	20	265
18	23	8	1	32	236	67	10	313
19	29	3	2	34	218	21	20	259
20	15	6	1	22	157	72	10	239
21	20	2	0	22	154	11	0	165
22	18	6	1	25	188	69	10	267
23	15	1	1	17	138	8	10	156
24	26	2	0	28	180	22	0	202
25	16	2	1	19	159	29	15	203
	288	105	30	423	2,775	1,069	321	4,165

Average problem / lesson:	9.3	10.2	10.7	9.8

3. Addition. Concept of addition using N-notation, equations, column addition, commutativity, three addends, solving addition equations (one missing addend), construction and use of addition tables, oral story problems with and without pictures to count.

4. Subtraction. Concept of subtraction as "take-away," equations, column subtraction, subtraction as the inverse of addition, oral story problems.

5. Geometry. Recognition of figures (square, circle, triangle, rectangle, line segment), concave and convex, open and closed, inside and outside, congruence with rotations and reflections, similarity with rotations and reflections, construction of rectilinear figures given vertices, counting sides and vertices, linear measure.

6. Games. "Reward" games used primarily for motivation.

7. Miscellaneous. Ordinals, liquid measure, time, readiness for fractions, number words.

The first eight lessons in Book 1 let the students learn to use the equipment and introduced them to formats and vocabulary which would be needed in following lessons. For example, Lessons E, F, and H in Book 1 were tests of the operational understanding of the words "top," "bottom," "middle," and "below."

In Book 2 the concept of sets was introduced using set braces with pictures of animals, toys, and other familiar objects. The vocabulary included "set," "brace," "member," "empty set," and "equal." Equality was introduced starting immediately with unordered rather than ordered sets, since experimental evidence has shown that this approach led to greater learning. All of the lessons in the first two books were easily mastered by the students, although the concept of an empty set was relatively difficult and continued to be so for several more books.

In Book 3, the concept of union of sets was introduced using the union symbol $\cup$. Except for problems involving the empty set, these lessons were also within easy grasp of the students. Practice in counting was started in Book 3. Since it is desirable to develop counting skills independently of skills in numeral recognition, the counting lessons used two numeral-free formats. In one format, the students were shown a picture and asked a question like, "Are there <u>four</u> houses?" to which they responded by touching one of the words "yes" or "no" that were displayed on the CRT. The second counting format consisted of a display of several rows of countable objects, and students were required to choose the row with the stated number of objects. The "yes/no" format, which was first used in Book 3, was preceded by a lesson introducing the words themselves, since it could not be assumed that beginning first graders could read them. The "yes/no" format was used in a number of counting lessons, and, in later books in other contexts; this format proved to be the most difficult of any used in the entire first-grade curriculum and was never mastered by some children. At a later time the same format was used very successfully with beginning second-grade students.

Book 4 was largely devoted to simple geometric concepts: squares; circles; triangles, and line segments. These lessons proved to be exceedingly simple, and the students gave evidence of enjoying them. These, and most other geometry lessons, were presented in a multiple-choice format.

In Book 5 there was an extension of the idea of union of sets to the solution of set equations (Lessons E, F and G). These problems, which are related to the problems of supplying missing addends in addition equations, were quite difficult and were aimed primarily at gifted children; children who failed to meet criterion on one of these lessons could be allowed by the proctor to bypass the remaining lessons. About 20 per cent of the students completed the sequence.

The numerals 0 to 4 were introduced in Book 6 and immediately related to counting members of sets. Although the initial lessons were relatively successful, the proctors and writers felt that it would have been more satisfactory to have introduced the numerals as "sight words" and later used them in counting lessons. The later lessons in Book 6 introduced N-notation and were quite unsatisfactory. The ideas are not too complex and have been taught with great success in many first-grade classrooms, but the vocabulary and sentence structure of the audio messages in the programmed lessons was too difficult for a large number of the students.

Addition was introduced in Book 7 with pairs of equations, one using N-notation, the other, arabic numerals. The task of relating these two equations was beyond the visual and conceptual comprehension of most children, many of whom had just learned how to count accurately. In later lessons, numeric equations were accompanied by small counting marks below each addend. Although these lessons were more successful, proctors felt the presentation was still too abstract for some children. These children quickly found that counting the marks would result in the correct answer, but could not readily see the relationship between marks and numerals. Thus, when marks were no longer displayed, they could not derive an algorithm.

The lessons in Books 8 and 9 provided further practice in set problems, counting, addition, and geometry. Book 10 included open and closed figures, counting sides of polygons, and identifying rectangles. These lessons, like others in geometry, were extremely successful.

Due to difficulties in maintaining the schedule of production, three books (Books 11, 12 and 13) were omitted from the programmed curriculum. Topics included in these books were coverd in the classroom.

Book 14 contained three lessons on linear measure; two of these lessons required the use of worksheets and rulers. Although some of the children had a little trouble keeping their worksheets in order, the difficulties were minor, and it was felt that even more use of supplementary materials could be made with children this age. Book 14 also covered lessons on counting, addition, etc.

Missing addend problems were introduced in Book 15; these problems proved to be the most difficult of any in the entire curriculum, and the teachers felt that the introduction to this subject should have been postponed until later in the curriculum in order to allow more practice in addition. The format of the introductory lessons consisted of relating equations of the form $a + b = \underline{c}$ with those of the form $a + \underline{b} = c$. This type of explanation was too abstract for many of the children who needed to be told in simple, specific language exactly how to solve the problems. For children who had difficulty reading equations correctly, lessons using large graphic numerals and signs were more successful than those in which smaller characters were displayed.

A sequence of lessons presenting the number words "zero" through "ten" was presented in Books 16 and 17. Many children who were poor readers found these lessons extremely difficult and frustrating. Children who failed several lessons of this type were given "dictionary" cards upon which the number words and their corresponding numerals were written.

The concept of subtraction that was introduced in Book 18 was difficult for many children to master. In the introductory lessons, marks were displayed above the equations with the appropriate number crossed out. Later, children were instructed to "cover up" the marks they wanted to take away. Many children found the marks too small to cover up and count accurately. Proctors again felt that the presentation was too abstract and that more extensive preparation by way of story problems and visual displays was necessary.

The geometry lessons in Book 19 concerned matching similar figures of different size and different degrees of rotation. Students continued to perform satisfactorily in these lessons. Subsets were introduced as enrichment material. If a student failed criterion in any of the lessons in this sequence, he was automatically branched around the remaining lessons. About 27 per cent of the students completed the sequence.

Further practice in subtraction, geometry, and counting was presented in Book 20. Several lessons stressed the inverse relationship between addition and subtraction. Despite extensive visual displays, few children saw any connection between problems of the type $a + b = \underline{c}$ and $c - b = \underline{a}$, and tended to use their fingers to solve each equation.

A general introduction to the concept of place value was included in Book 21. Exercises were primarily concerned with counting from 10 with a dime and n pennies displayed on the film. Almost every child required a proctor's assistance in learning the counting algorithm, and teachers felt that some display other than money should have been used for this introduction.

The number line as an aid to finding sums above 10 was presented in Book 21. Many children were confused by this approach, and most relied on fingers or manipulative objects to solve equations.

Books 23 to 25 were completed by only a small percentage of the students as shown in Table 3. Topics presented in these books included counting by ten's and five's, telling time, and missing addends in sums above 10.

Classroom work. The activities carried out in the classroom were in one of the following categories: (a) use of physical objects to introduce concepts presupposed by the programmed lessons; (b) work originally planned as programmed lessons; (c) remedial work for individual children; and (d) enrichment material for individual or groups of children.

A discussion of the above kinds of classroom activities follows.

Introduction of concepts presupposed by the programmed lessons. At the beginning of the year from September 30 until the first group began programmed instruction on October 27, the four different groups met in the laboratory classroom each day for approximately 20 minutes.

The activities carried out in the classroom were intended to give the children a variety of manipulative experiences which the programmed lessons presupposed. At the same time it was important to exercise care that no tasks introduced in programmed lessons were first introduced in the classroom setting, since this would make meaningless any data collected from the programmed lessons.

We began by doing exercises in one-to-one correspondence. (Since knowledge of counting was to be tested during the first month of school, reference to number in this exercise was strictly avoided.) An example of the kind of activity done was to hold up a given number of pencils and to instruct the children, "make yours look just like mine." The terms "as many as" and "the same number of things as" were also introduced. The tasks ranged in complexity from the simple task of matching like objects one-to-one through three intermediate stages to matching pictures of unlike objects one-to-one. The amount of practice necessary at each of the intermediate stages was determined to a great extent by the children's ability or lack of ability to count. (Though no mention of counting was made, those children who already knew how to count immediately chose this method of solving their problems.) When three or fewer objects were involved, mistakes were uncommon. When four or five objects were involved, errors increased, and when more than five objects were involved, errors were quite common. Methods of correcting or verifying answers were devised by the children.

These activities led to a development of the concepts of more and less. Few children had any difficulty with the concept of more, but almost every child had trouble with less. The word "less" seemed completely unfamiliar to many children, and even when stressed as being the opposite of "more" or as meaning "not as many as," "less" was the most difficult word introduced to the children.

Ancther concept the children needed to understand in order to do some of the programmed lessons was that of giving yes or no answers to questions. As might have been expected, questions requiring yes answers were quite easy, while those rquiring no answers were considerably more difficult.

Exercises using the words top, middle, bottom, before, and after were given, since knowledge of these words was presupposed in some of the machine lessons. There was little difficulty with these words in the limited contexts in which they were used.

After the children had been tested, they were introduced to counting through 5, and later to counting through 9. There was considerable discrepancy in the abilities of most children to rote count and in their abilities to "Show me seven blocks," or to give an answer to "How many blocks do I have?" The slower children required a period of several weeks to develop their ability to count to 9.

The more advanced children were able to generalize that (a) we need 1 more to make the next number; and (b) a number is 1 more than the number before it. Many exercises in completing patterns were necessary before those generalizations were made.

The children also worked on concepts of <u>the same</u>, <u>more</u>, and <u>less</u> when comparing two groups of objects. All of these activities were done using manipulative materials.

<u>Sets</u> of objects were introduced, as was the concept <u>union of sets</u>. Both topics were introduced using manipulative objects, and no notation was used in these exercises. Considerable attention was given to identifying sets as having particular properties in common, leading up to identifying sets with the same cardinality. The children had no difficulty with the concept of the <u>empty set</u>, as long as it was referred to as "the set with nothing in it." The word "empty," however, was unfamiliar to almost all these children, and seemed to be a somewhat difficult one for the children to learn. Thus, reference to "the empty set" increased the difficulty of tasks involving the empty set.

Linear measure was introduced in the classroom, first using non-standard units, and later using standard units. Most of the children had no idea of how to make a linear measurement.

Telling time to the hour, recognizing various coins, and counting money were also introduced in the classroom.

Considerable attention was given to writing the numerals, and late in the year, to writing number sentences. In general, the writing of number sentences was done in connection with story problems given orally.

Work originally planned as programmed lessons. Several times during the year, children remained in the classroom while further programmed lessons were prepared.

During one such period, the groups worked on addition, since this had just been introduced by programmed lessons. The introduction was without any direct reference to manipulative objects, and most children were having considerable trouble. The classroom activities then were concerned with using manipulative objects to illustrate addition, and with relating such manipulations to the symbols. The obvious need of children to count in order to solve addition problems led us to provide a wire with 10 beads for each child to use either in the classroom or at his terminal. As the children learned the various combinations, they used the beads only for those combinations they still did not know.

We also played a number of games leading to providing the missing addend. As long as the games were played orally without showing the addition sentence, almost every child could answer correctly. When the number sentence was written on the chalkboard to be read by the children, errors increased dramatically. This was true even for those children who could read the equations. Apparently, they still were not comfortable relating written symbols to physical experiences.

At another time it was decided that the topics in Books 11, 12, and 13 should be taught in the classroom, while succeeding books were being programmed. Topics included in this classroom work were (a) more addition (both $a + b = \_\_\_$, and $a + \_\_\_ = c$); (b) number sequences; and (c) introduction to the number line.

Remedial work. The most frequent topics for which children were sent to the classroom were addition and subtraction. Throughout the year, whenever a child had excessive difficulty with a topic he encountered in programmed material, he was sent to the classroom for remedial work. The time a child spent with a teacher varied from a few minutes to several days, depending on his needs.

Enrichment work. At various times throughout the year, individual children or entire groups were in the classroom because of machine failures. So as not to interfere with data collection for topics presented in programmed material, enrichment work was provided. One such enrichment unit was in constructive geometry in which approximately half the children learned to manipulate a compass and straightedge. They also learned to read and follow directions for making some simple geometric constructions.

Other enrichment topics were extensions of subjects presented in programmed lessons, such as sets, patterns, and sequences. Game approaches were employed in the enrichment work for these topics.

3.2. Reading

It is assumed that the English speaking child brings to the initial reading task a relatively large vocabulary and at least an operational knowledge of English syntax. He has a knowledge of the language that enables him to communicate with his peers and with adults; therefore, the primary goal of initial reading is not to teach the language, but to teach the orthographic code by which our spoken language is represented.

In attempting to teach a code, the most reasonable approach is to begin not with all the irregularities and exceptions, but rather with the regular and consistent patterns. This position is not unique to the Stanford Project. It has been advocated by linguists for some years (Bloomfield (1942)[1], Fries (1963)[2]) and has been implemented in several "linguistically oriented" reading series. The sequencing of monosyllabic patterns (Table 4) and certain extensions and refinements of the basic notions, as stated by the above-mentioned authors, constitute the original work in curriculum design carried out by the Stanford Project.

Insert Table 4 about here

The psycholinguistic rationale of the curriculum may be found in Rodgers (1967)[3] and Hansen and Rodgers (1965)[4]. Rodgers (1967) provides a concise summary of our goals and procedures.

> "From a practical point of view, our program is an attempt to provide non-readers with some limited analytic skills--phonological, morphological, syntactic and semantic--and some considerable confidence in the use of these skills. It is not our intention to teach the child all of the sound-symbol pattern correspondences, all of the morphological variations, all of the usages of frequent vocabulary items, or all of the sentence patterns of English. It is our intention to give the student enough skill and self confidence to involve him in that confrontation known as beginning reading. We believe it is the ability to make reasonable inferences concerning unfamiliar or unobserved sequences on the printed page that we are ultimately trying to teach in reading.
>
> "We have defined the Stanford approach to initial reading as applied-psycholinguistic. Hypotheses about the nature

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[1]Bloomfield, L. Linguistics and reading. Elementary English Review, 1942, 19, 125-130.

[2]Fries, C. Linguistic and Reading. New York: Holt, 1963.

[3]Rodgers, T. S. Linguistic considerations in the design of the Stanford computer-based curriculum in initial reading. Technical Report 111, Institute for Mathematical Studies in the Social Sciences, Stanford University, 1967.

[4]Hansen, D. N., & Rodgers, T. S. An exploration of psycholinguistic units in initial reading. Technical Report 74, Institute for Mathematical Studies in the Social Sciences, Stanford University, 1965.

TABLE 4

Reading Curriculum Lesson Sequence

LEVELS	vc	cvc	ccvc	cVc~~e~~ ccVc~~e~~ cccVc~~e~~	cV ccV	cvcc ccvcc	cvvc ccvvc	cvv ccvv cccvv	cccvc cvccc
I 13 lessons	ac	cac							
II 19 lessons	ic	cic	ccac						
III 23 lessons	ec	cec	ccic	cAc~~e~~ ccAc~~e~~	cA				
IV 29 lessons	See Note 2.								
V 23 lessons	oc	coc	ccec	cIc~~e~~ ccIc~~e~~	cI cY cE ccY ccE	cacc			
VI 36 lessons	See Note 2.						ai oo ight	ay	
VII 43 lessons	uc	cuc	ccoc	cEc~~e~~ cOc~~e~~ ccOc~~e~~ cUc~~e~~ ccUc~~e~~	cO ccO	cicc cecc ccacc ccicc ccecc			a ccc i c a e c i ccc e
VIII 65 lessons	See Note 2.		ccuc			cucc cocc ccucc ccocc	ow oy ee ie ea ei ew		o cccuc cuccc o

Note 1: c = any consonant; v = any short vowel; V = any long vowel.
Note 2: Less frequent and less regular variations of preceding patterns (e.g., post-vocalic r, w).

of the reading process, the nature of learning to read, and the nature of teaching reading have been constructed on the basis of linguistic information about the structure of language, empirical observations of language use, and an analysis of the function of the written code. These hypotheses have then been tested in experimental situations, structured to represent as realistically as possible actual learning and teaching situations. On the basis of experimental findings, these hypotheses have been modified, retested and ultimately incorporated into the curriculum as principles dictating presentation variables and values. This is, of course, somewhat of an idealization since very little curriculum material can be said to have been the perfect end-product of rigorous empirical evaluation. We would claim, however, that the basic tenets of the Stanford program have been formulated and modified on the basis of considerable empirical evidence. It seems probable that these may be further modified or re-formulated on the basis of the considerably greater amount of empirical evidence which will be available as the result of a year's CAI experience with classes of beginning readers."

It is unrealistic to claim that all initial reading instruction can be accomplished in a 20-minute session on the CAI system. Rather, the program is viewed as one of cooperative effort between the normal classroom reading instruction and the Stanford CAI project. Teachers were introduced to the CAI curriculum and received regular reports on student performance. In return, classroom teachers informed us of the kind of instruction conducted in their classes.

Description of the reading curriculum. The Stanford CAI Reading Curriculum was divided into four broad areas of concentration: (a) decoding skills; (b) comprehension; (c) games and other motivational devices; and (d) review. The lesson material and teaching strategies will be discussed briefly for each area. Figure 2 shows a block-level flow chart for Level III, Lesson 9.

Insert Figure 2 about here

3.2.1. Decoding Skills

Letter teaching. The 26 letters are taught in three sets of nine letters; the third set contained a repetition of one letter from one of the preceding sets. The first set of nine letters was taught just prior to Level I, Lesson 1, and contained the nine letters used in the first five lessons. The second set was sequenced between Lessons 5 and 6 of Level I, and the third set appeared just before Level II, Lesson 1. The three sets were constructed as follows.

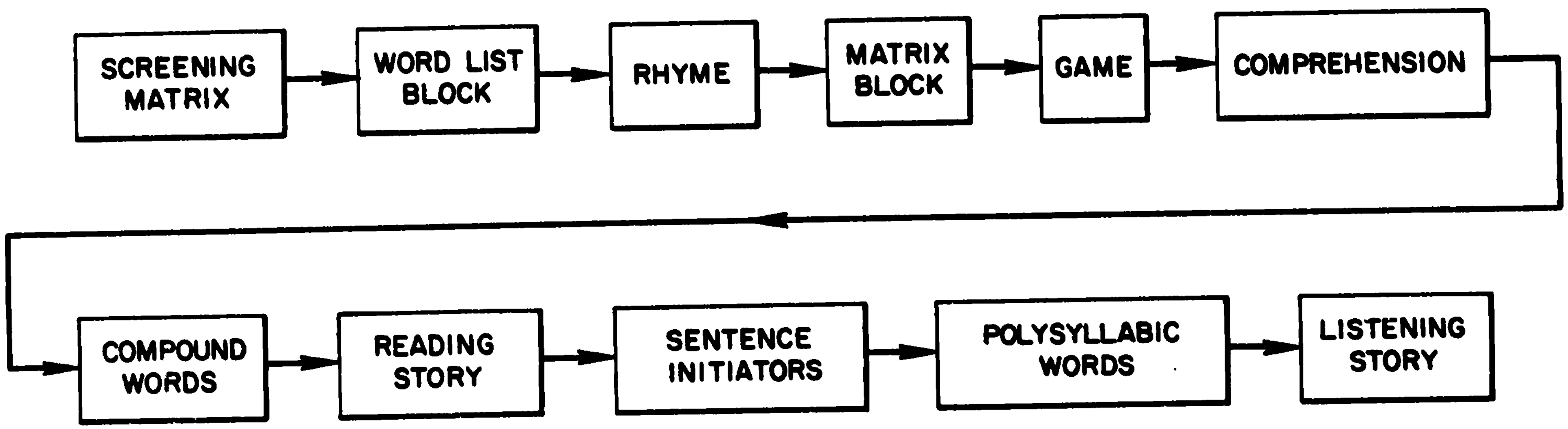

Fig. 2. Block Level Flow Diagram, Lesson 9, Reading

$$S_1 = \{h, c, t, n, s, a, m, f, d\}$$

$$S_2 = \{g, i, v, p, w, j, b, r, l\}$$

$$S_3 = \{o, x, z, k, e, q, u, y, g\}$$

Each set was broken into six subsets of three letters. Each subset was called a list (L_{n1}, L_{n2} ... L_{n6}) and had the following characteristics:

$$L_{n1} + L_{n2} + L_{n3} = L_{n4} + L_{n5} + L_{n6} = S_n.$$

$$\left.\begin{array}{l} L_{n1} \\ L_{n2} \\ L_{n3} \end{array}\right\} \quad \text{Each contains three elements of } S_n \text{ with maximal visual differences.}$$

$$\left.\begin{array}{l} L_{n4} \\ L_{n5} \\ L_{n6} \end{array}\right\} \quad \text{Each contains three elements of } S_n \text{ with minimal visual differences.}$$

For example:

$$L_{11} = \{h, c, t\}$$

$$L_{12} = \{n, s, a\}$$

$$L_{13} = \{m, f, d\}$$

$$L_{14} = \{c, a, d\}$$

$$L_{15} = \{n, h, s\}$$

$$L_{16} = \{t, f, m\}$$

Minimal audio differences were avoided, and this restriction was an overriding consideration in constructing each list. For example, by the rule of minimal visual differences, L_{15} should have been $\{n, m, h\}$, but the audio confusion of $\{m\}$ and $\{n\}$ had to be avoided.

Each list was taught in a paired-associate paradigm as in the following example:

$\boxed{h\ c\ t}$ appeared on the CRT, and the student was requested to touch h. After the student responded, a smiling or frowning face appeared, depending on whether the response was correct or incorrect. An arrow was displayed over $\overset{\downarrow}{h}$ and the student heard the audio message "This is h."

The order of the three letters was randomly changed on the CRT, and the cycle was repeated for another letter. Three responses (i.e., one response to each of the three items) constituted a trial. The order of response requests was random for each trial.

Criterion was set at two successive errorless trials. The probability of achieving criterion by guessing was approximately 0.001. When a student met criterion, he branched to the next list.

A limit of 20 trials was set for any one list. If criterion was not met within 20 trials, the student branched to a same-different task, using the same list.

The student saw

h	n
yes	no

and was asked if the letters were the same. (He was previously trained to make yes/no responses.) A smiling or frowning face was displayed, depending on the response, and again an arrow and feedback audio message was presented independent of the actual response. Another letter from the list was displayed, accompanied by the same or a different letter. Again, once through the list was considered a trial. Criterion in this task, however, was three errorless trials. The probability of reaching criterion by guessing was approximately 0.002. If criterion was met, the student branched to a match-to-sample task on the same list. If criterion was not met within 20 trials, a proctor call was given, and the student was taken off the system for remedial instruction in the off-line classroom.

The match-to-sample task differed from the original task only in that the letter to be identified was displayed on the projector screen.

Projector	Scope
h	c h t

Criterion was two successive correct trials with a limit of 20 trials. If a student failed to meet criterion in the match-to-sample task, he was taken off-line for work in the remedial room.

If a student met criterion on the match-to-sample task, he made a second pass through the main-letter identification task. Failure to meet criterion on this second pass placed the student in the off-line room for further remedial instruction.

Each list (L_{11}, L_{12} ... L_{36}) was accompanied by the two types of remedial loops described above, and successful completion of each list was prerequisite to enter or continue with the regular lesson material.

The following is a description of the off-line letter identification activities for the children who needed remedial work. The remedial tasks were based on minimal contrasts that used a highlighting scheme to emphasize the minimal contrasts.

The first set of activities centered around the discrimination of the likenesses and differences of pictures. The student saw two pictures and was requested to answer yes or no to the question, "Are they the same?" The second set of activities focused on discrimination of the letter forms.

The following sequence for the letter a exemplifies the progression of instruction for each letter.

	Display		Task
1.	a c	yes no	Are the letters the same?
2.	a	c a	(Point to a single letter in box.) This is a. Touch the letter a.
3.	a	a c n	(Same task as number 2)
4.	a	at in	(Point to the single letter.) This is a. Touch the word with the letter a in it.
5.		a c n	Touch a.
6.		it an	Touch the word with the letter a in it.

7. Criterion test (cumulative criterion)

a c n	Touch a. (Test all letters given up to this point.)

If a student failed criterion in off-line instruction, he was referred to the classroom as unready to benefit from computer-assisted reading instruction. The student was returned to the Laboratory when the teacher felt he had reached the proper level of readiness and began work at the letter task where he had failed in the original exposure.

Word-list learning. This section may be described as a set of paired-associate tasks where the stimulus is the verbal pronunciation or pictorial representation of a word (or both), and the response is the correct identification of the appropriate written word in a list of written words. The lists for any given lesson were composed of words generated by the rhyming and alliterative patterns presented in that lesson.

Quantitative learning models, appropriate to the paradigms in this section but similar in nature to those existing for classic paired-associate learning (Atkinson, Bower, and Crothers, 1965)[1], were developed to describe acquisition processes and to assess the effects of learning and forgetting.

[1] Atkinson, R. C., Bower, C. H., & Crothers, E. J. An introduction to mathematical learning theory. New York: Wiley, 1965.

Five problem types (PT) containing approximately six problems each were included in this section. Each PT represented a step in a cue-fading technique. The five PT's are:

PT 1 - Cues: picture, orthography, and audio;

PT 2 - Cues: picture and audio;

PT 3 - Cues: audio only;

PT 4 - Cues: picture only;

PT 5 - Criterion Test. Cues: audio only.

The student responded to a set of cues by touching a word in a list of words on the CRT. Each student response received immediate feedback. If a response was correct, it was reinforced. If it was an error, the correct answer was indicated by an arrow, and an overt correct response was required before the next problem was presented, otherwise, the student branched to appropriate remedial problems. This is a general teaching strategy adhered to throughout all the lesson materials, except in the case of the criterion tests. PT 5 was a criterion test and was similar to PT 3, except that no feedback or correction was given on the first presentation of the list. If the student met criterion (i.e., no errors) on the first cycle, he left the word-list presentation block. If he did not meet criterion, he returned to the task described in PT 2, branched past PT 3, and was presented with those items in PT 4 which he missed in PT 5. He then made a second cycle through PT 5 with correction and optimization to one initial correct response for each item.

The problem route for these five problem types is represented by the flow diagram in Figure 3. Correct response routes are indicated by solid lines and remedial branches by dotted lines.

Insert Figure 3 about here

The optimization routine referred to in Figure 3 cycled the student through the list of response requests, repeating only those items to which incorrect responses were given until each item received one initial correct response.

Remedial materials for word-list presentation sections. Early studies designed to test the feasibility of the lesson material indicated the performance of a small percentage of the students was lower than anticipated on the word-list materials. It was difficult at that time to specify all the problems of these slow learning students, since the learning difficulties were varied and complex. The learning problems, however, were grouped into four categories:

1. A need for finer discrimination of the initial or final units of stimulus words, either as letters, or as sound patterns, or both.

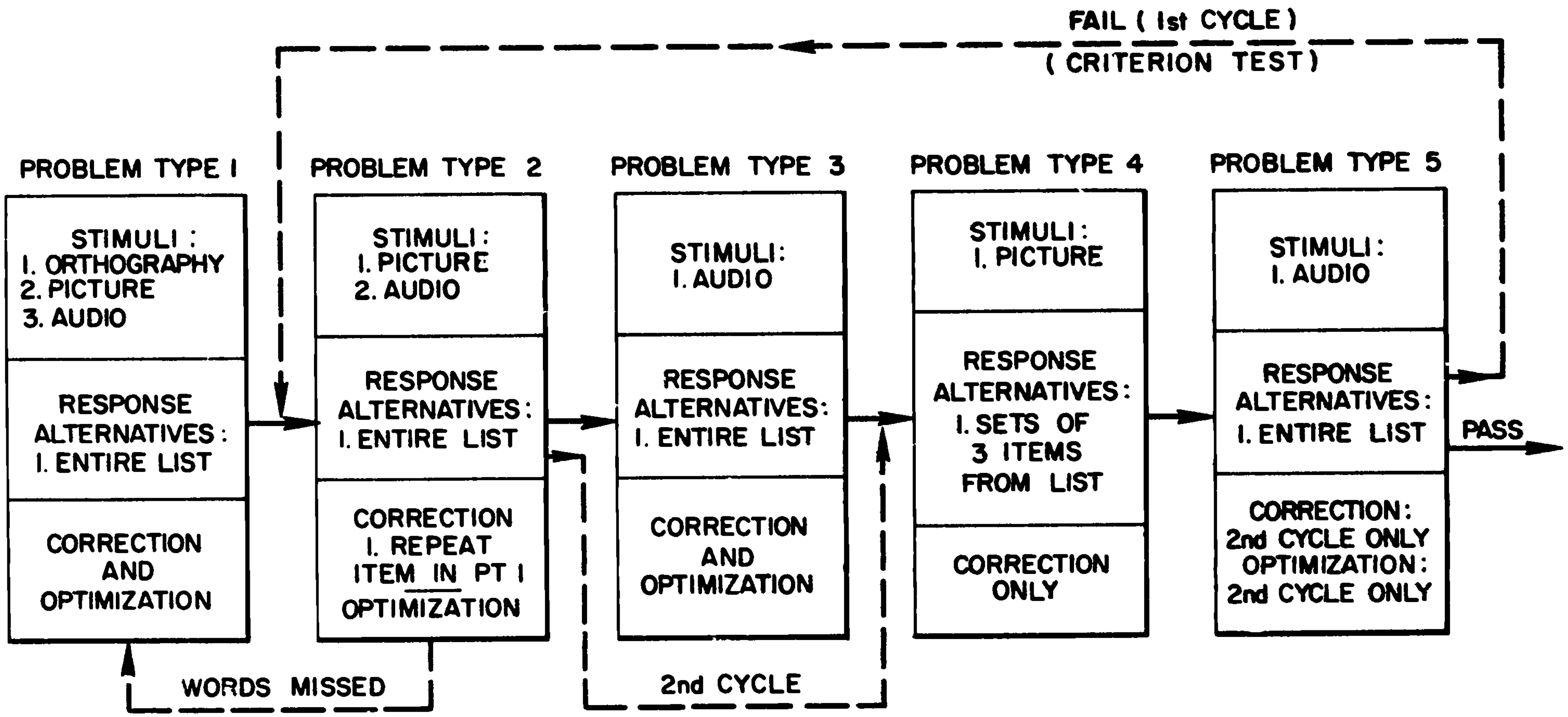

Fig. 3. Flow Diagram for Reading Word-List Block

2. A need for practice with fewer words. The memory-processing capacity of some students seemed to be overtaxed.

3. A need for extensive practice on given words that troubled a particular child.

4. A need for a richer semantic context within which to relate new words.

Four sets of remedial materials to supplement the word-presentation section were developed to give additional specific practice to those students experiencing one or more of the above problems. The four remedial sets were called: (a) letter-word saliency; (b) alliteration and rhyming; (c) rich sentences; and (d) reduplication and sentence initiator.

The four blocks of remedial-word presentation materials were sequenced after PT 1 in the word-list presentation block as indicated by Figure 4. In a conventional sequence for the word-list presentation block in PT 2 (Figure 3), the picture was shown on the projector without

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Insert Figure 4 about here

----

the printed word, and a touching response to the appropriate word on the scope was requested. By setting a counter at the beginning of PT 2, it tallied the errors for each initial presentation cycle, but not for the optimization routines. At the end of the first cycle, the counter was examined. If its contents exceeded a predetermined value (e.g., 50 per cent of the number of response requests) the student branched to the first assigned block of remedial material.

After completion of the remedial block, the student returned for another cycle through PT 2. The error counter was set again to zero and the above operation was repeated. If the student again had an error rate of greater than 50 per cent, not including the optimization routine, he branched to the second assigned block of remedial material. The branching process was repeated if necessary until all four blocks of remedial material were exhausted. In the case where a student completed a fifth failing cycle in PT 2, he branched out of the instructional material, and the proctor was called automatically. Thus, a student could receive from zero to four remedial presentations, according to the evaluation, after a cycle through PT 2.

If a student met the criterion for Problem Type 2, he proceeded through Problem Types 3, 4 and 5 to the word-criterion test, and the decision counter was again set at zero. If a student met criterion, he proceeded to the next section of lesson material. If his performance in the test did not meet criterion and his error rate was less than 50 per cent of the number of response requests, he branched to PT 2. If, however, the error rate exceeded 50 per cent, he branched directly

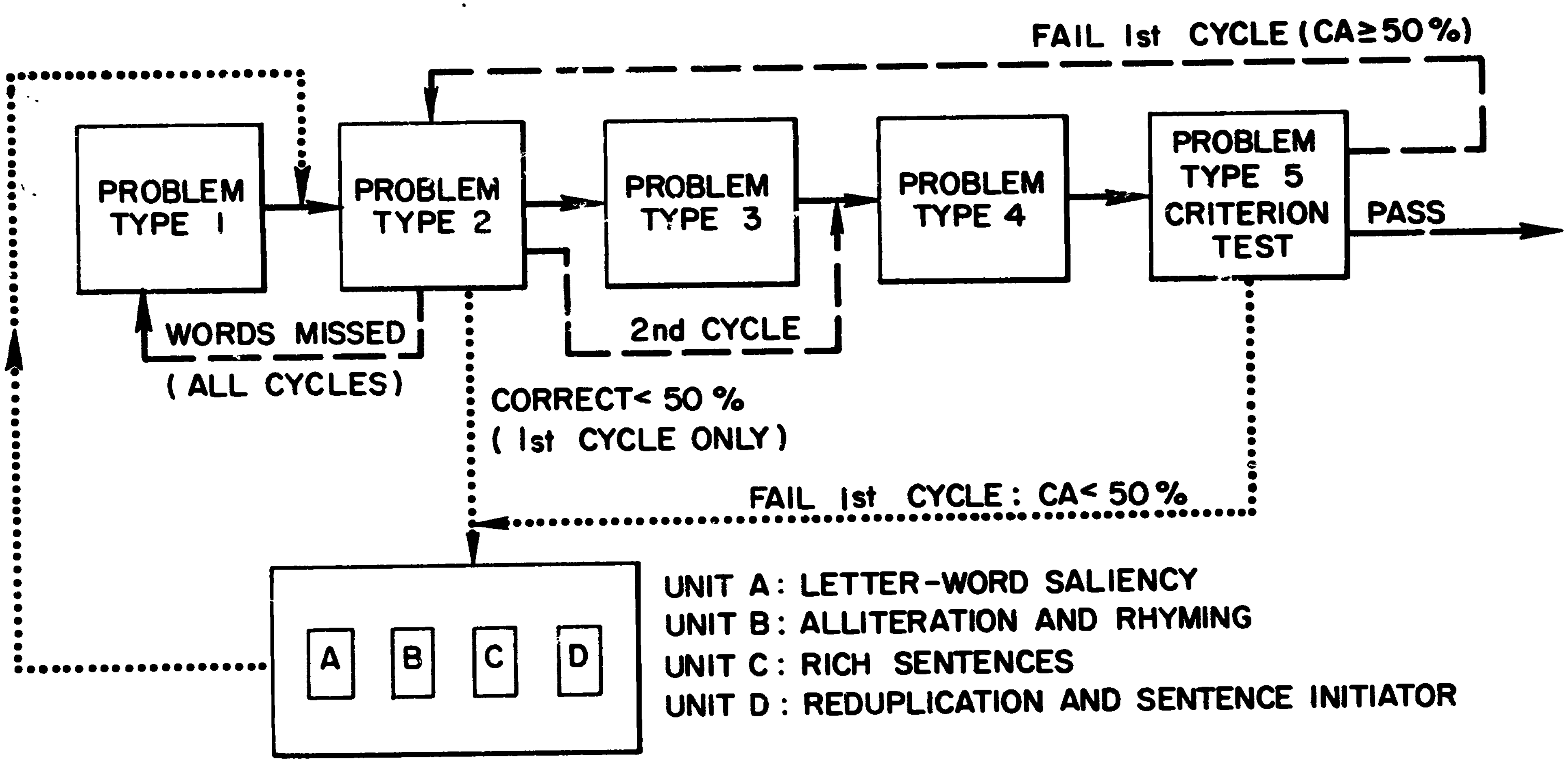

Fig. 4. Flow Diagram for Word-List Block with Remedial-Reading Units

to the next of the remaining remedial sections before being recycled through PT's 2, 4 and 5. In a second cycle through PT 5, the student was given an optimization routine and was allowed to proceed to the next section of the curriculum. Therefore, there were two ways for a student to reach the remedial material. The first was to exceed the error criterion for PT 2, and the second was to exceed the error criterion during the first cycle of PT 5.

The same general procedures applied to either method of entering the remedial material. It must be noted, however, that only one entrance to the remedial material could be made from the word-list criterion test, since the second pass through the criterion test was purely an optimization routine with no error counter set for second branching to remedial loops. An evaluation of the remedial material and the remedial sequence follows. For each word-list presentation section (i.e., for each lesson) the four blocks of remedial material were ordered randomly. The response data for students who received remedial material were analyzed off-line to see if the increments in performance following each of the remedial blocks differed significantly from each other.

Matrix construction. Certain rhyming and alliterative word patterns were considered regular (i.e., certain graphic sequences corresponded without exception to certain sound sequences). Fries (1963)[1] and Bloomfield (1942)[2], among others, suggested that a key concept in learning to decode English print was patterned word regularity. This decoding concept was used in the Stanford materials via the sequencing of monosyllabic patterns as shown in the Lesson Sequence, Table 4. The sounding matrix is an instructional practice technique in learning to associate orthographically similar sequences with appropriate rhyme and alliteration patterns.

Rhyming patterns were presented in the columns of the sounding matrix.

	an
r	ran
f	fan
c	can

Alliteration patterns were presented in the rows of the matrix.

	an	at	ag
r	ran	rat	rag

The matrix was constructed one cell at a time. The initial consonant of a consonant-vowel-consonant (CVC) word was termed the initial unit, and the vowel and the final consonant were termed the

[1]Fries, C. Linguistics and reading. New York: Holt, 1963.

[2]Bloomfield, L. Linguistics and reading. Elementary English Review 1942, 19, 125-130.

final unit. This division was continued later when the words were composed of consonant clusters and diphthongs. The intersection of an initial unit row and a final unit column determined the entry in any cell.

The problem format for the construction of each cell was divided into four parts: Parts A and D were standard instructional sections, and Parts B and C were remedial sections. The flow diagram (Figure 5) indicates that remedial Parts B and C are branches from Part A and are presented independently or in combination.

Insert Figure 5 about here

The following example of a matrix cell construction is presented in some detail in order to highlight the instructional sequence and remedial branches. The student saw the empty cell with its associated initial and final units and an array of response choices. He heard the audio message indicated by response-request number 1 (RR 1) as indicated in Figure 6.

Insert Figure 6 about here

If the student made the correct response (CA) (i.e., touches <u>ran</u>) he continued to Part D where he saw the word written in the cell and received one additional practice trial (Figure 7).

Insert Figure 7 about here

In the course of an errorless trial, the student heard the word pronounced three times and was asked to identify and pronounce it twice.

In the initial presentation in Part A, the multiple-choice items were designed to identify three possible causes for error: (a) the initial unit is correctly identified, but the final unit is not; (b) the final unit is correctly identified, but the initial unit is not; (c) neither the initial unit nor the final unit is correctly identified.

If, in Part A, the student responded with <u>fan</u> he branched to remedial section B, where attention was focused on the initial unit of the cell (Figure 8).

Insert Figure 8 about here

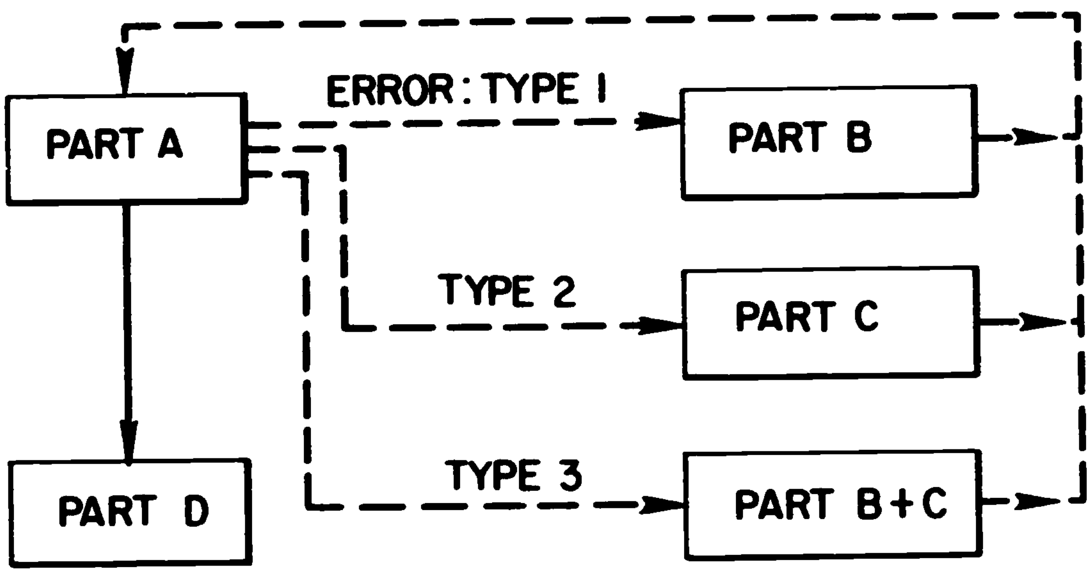

Fig. 5. Matrix Flow Diagram,
Reading Project

an

r $\boxed{}$

rat
bat
fan
ran

RR 1: Touch and say the word that belongs in the empty cell.

CA: (Branch to Part D)

WA 1: No, $\left\{\begin{array}{l}\text{rat} = \text{final} \rightarrow \text{C}, \rightarrow \text{A} \\ \text{fan} = \text{initial} \rightarrow \text{B}, \rightarrow \text{A} \\ \text{bat} = \text{other} \rightarrow \text{B}, \rightarrow \text{C}, \rightarrow \text{A}\end{array}\right.$

$\downarrow$CA

WA 2: No, touch and say ran.

Fig. 6. Matrix Problem, Part A,
Reading Project

an

r $\boxed{\text{ran}}$

RR 1: Good, you have put ran in the cell. Touch and say ran.

CA: Good, ran. ($\rightarrow$ next problem)

$\downarrow$CA

WA: No, touch and say ran.

Fig. 7. Matrix Problem, Part D,
Reading Project

$$\begin{array}{cc} & \text{an} \\ \text{r} & \boxed{} \\ & \text{f} \\ & \text{r} \\ & \text{d} \end{array}$$

RR 1: Touch the initial unit of the empty cell.

CA: Good.

WA: 1 ($\overset{\downarrow}{\text{r}}$ $\boxed{}$) No, this is the initial unit of the cell 1 so touch this.

$$\text{CA} \rightarrow \begin{pmatrix} \text{f} \\ \text{r} \\ \text{d} \end{pmatrix}$$

Fig. 8. Matrix Problem, Part B, Reading Project

If a correct response was made, the student returned to Part A of the problem for a second attempt which was optimized for a correct response. If an error response (WA) was made in Part B, the indicator was displayed above the initial unit beside the cell at the point indicated by the first circled superscript 1 in the audio message and held until the second superscript 1' . At the completion of the response request, the indicator was placed beside the correct response area and held until a correct response was made ($\underset{\rightarrow}{CA}$).

If, in Part A, the student responded with rat, he branched to remedial section C, where additional instruction was given on the final unit of the cell (Figure 9).

Insert Figure 9 about here

The procedures in Part C were similar to those of Part B. It should be noted in the remedial section that the initial letter was never pronounced (Part B), but the final unit was always pronounced (Part C).

If, in Part A, the student responded with bat, he branched through both initial and final unit remedial work.

When the student returned to Part A after completing a remedial section, a correct response advanced him to Part D as indicated. If a wrong-answer response was made on the second pass, the indicator arrow was placed beside the correct response area and held until a correct response was made. If the next response was still an error, a message was sent to the proctor and the sequence repeated from the beginning.

A correct response on Parts A and D, advanced the student to the next word cell of a matrix that had a problem format and sequence identical to that just described.

The individual cell building continued until the matrix was complete. The majority of the matrices in the lesson material contained from 6 to 12 words and nonsense syllables. Nonsense words were considered legitimate cell entries under the following constraints:

1. Nonsense items are occurring English syllables.

2. Nonsense items are not used that represent regular but unconventional spellings for common monosyllabic words. For example, although sed represents a regular spelling for the initial English syllable in words such as sediment, it would not be presented in matrix format since it would be considered an unacceptable spelling for the homophonous monosyllabic word said.

3. The proportion of nonsense words in the matrix is less than 40 per cent of the total cell entries.

an

r $\boxed{r}$

an
at
ag

RR 1: Touch and say the final unit of the cell.

CA: Good.

an

WA: 1 ($\boxed{}$) No, an is the final unit of the cell 1' so touch and say

CA → (an / at / ag)

Fig. 9. Matrix Problem, Part C, Reading Project

When the matrix was complete, the entries were reordered and a criterion test over all cell entries was given as shown in Figure 10.

Insert Figure 10 about here

The student received randomized requests to identify the cell entries. Since the first pass through the criterion matrix was a test trial, no reinforcement or correction was given. Errors were categorized as initial, final, and other. Remedial exercises were provided for both initial and final errors. The branching procedure was similar to that in the cell construction section with one exception. While the branching in the cell construction block was contingent on each separate response, the branching in the criterion test was contingent on the total performance in the test. If the percentage of total errors exceeded some specified criterion percentage (e.g., 20 per cent of the total responses) the category registers were examined. If all the errors were recorded in one category (initial or final), only the remedial material appropriate to that category was presented. If the errors were distributed over both categories, both types of remedial material were presented. This material is highly similar to conventional phonics exercises.

The standard optimization scheme for which an initial correct response was obtained for each item was used for all sections of remedial material.

After working through one or both of the remedial sections, the student looped back for a second pass through the criterion matrix. The second pass was a teaching trial as opposed to the initial test cycle; the student proceeded with the standard correction and optimization routines.

Compound words. The approach to compound words assumed the existence of a learning-transfer process in which the child knows how to read one of the two elements that form the compound word. The learning task consisted of reviewing this known word and learning the unknown part of the compound. In addition, the child must comprehend the conventional meaning of the compound word, as well as its role in a fairly rich sentence. Thus, we used compound words to study how much children can transfer partial reading mastery (i.e., recognition of one of the two words in the compound) to a variety of reading contexts.

Compound words were introduced in Level III and were initially composed of two known monosyllables (e.g., bat and man were mastered prior to the presentation of the compound batman). Sequences made up of five compound words with only one known element followed. Words were selected by: (a) frequency of appearance in initial reading materials; (b) imaginative sentence possibilities for a semantically rich context; and (c) the opportunity to vary the known word in initial and final positions in the five compound words (e.g., hatbox, firehat, hatband).

	at	an	ag
f	fat	fan	fag
r	rat	ran	rag
c	cat	can	cag

Touch and say:

RR 1: ran

RR 2: cag

RR 3: rat

⋮

Fig. 10. Matrix Criterion Test, Reading Project

Polysyllabic words. Our approach to noncompound polysyllabic words focused primarily on the role of stressed syllables in their relationship to verbal rehearsal and memory processing. We hypothesized that polysyllabic words with stress on the first syllable and a reduced or neutral vowel (usually transcribed as shwa (ə)) in the final syllable was most easily learned. In the Stanford Reading Curriculum, the acquisition of polysyllabic words is, as with compound words, a transfer learning process in which the first syllable of a polysyllabic word follows the pattern previously taught in the word list and decoding exercises. The stress and the number of syllables involved in the sequence were tightly controlled. The precise rules for sequencing polysyllabics were: (a) the words are, at first, bisyllabic; (b) the first syllable of the word is stressed; (c) the vowel of the final syllable is represented as phonemic /ə/, excepting /iŋ/, /liy/, /iy/; (d) the first syllable is regular in that it follows the pattern learned in the word list and matrix exercises; (e) the word is monomorphemic where possible; and (d) the words are found in the Lorge-Thorndike Word List (1944)[1].

Using these rules, the unstressed second syllables shown in Table 5 were added to an appropriate vocabulary item to form a polysyllabic word.

Insert Table 5 about here

Polysyllabic words were introduced in Level IV. First presented were double rhymes in which the list words for a given lesson were both graphemically and phonemically alike, except for the initial consonant (e.g., bitter, litter). Subsequently, words came in which the second syllables rhymed and represented morphemically similar elements (sapling, starling). In general, polysyllabic words of high frequency and useful in the story material were selected. It was assumed the words were understandable to the children, although no semantic criteria were specified.

The sequence of polysyllabic vocabulary allowed for a build-up from two-to three-syllable words. Direct systematic variations which were evaluated for their influence on the learning process were given between monomorphemic and polymorphemic word entries.

The lesson structure for polysyllabic words consisted of a sequence of approximately five words. For each pattern type (double

[1]Thorndike, E. L., & Lorge, I. The Teacher's Word Book of 30,000 Words. New York: Columbia Univ. Bur. of Publ., 1944

TABLE 5

Unstressed Second Syllables,
Reading Curriculum

Initial Syllable + $\left\{ \begin{matrix} \text{əC} \\ \text{CəC} \end{matrix} \right\}$				Stem + V	Stem + CV	Stem + CəC
age	el	ic	on	y	ly	let
al	le	ing	or			ling
ar	en	ip	ot			ness
	er	it	ow			
	et					

rhyme, second syllable rhyme, morphemic or non-morphemic second syllable) the child received a screening test similar to the matrix screening test. The child was asked to touch the cell where the two elements joined, such as lad + der forming ladder. If the child erred, he was presented with a rhyme using the words from the screening test, followed by simple phonemic-graphemic decoding exercises adjusted to that particular pattern of polysyllabics. The child who performed successfully on the screening test, and the child who was presented with the phonemic-graphemic exercises then proceeded to a lesson using two words from the screening test and three to four others which followed the pattern presented.

Sentence initiators. In reading written discourse, our learning objective was to train the initial readers to pronounce sentences with conventional intonation. A common reading behavior for beginners was to give "final-word stress" to each of the words in a sentence. We wanted to teach the child to adjust his timing, pitch, and stress contours to read sentences with intonation patterns commonly found in speech. This learning task became significant when one becomes aware that our CAI system does not include a speech-analysis device nor is such a device even technologically available at this time. Therefore, the initial reader had to be his own speech analyzer in this section of the Stanford Reading Lessons.

The virtue and logistic nuisance of any CAI system is the required specification of all the time intervals for each of the instructional and reinforcement events within every problem. In this, as well as other sections of the lessons, the pacing feature of the CAI system was used to accelerate the reading-speech output of the children and, consequently, pushed the children to approximate the speed and rhythms of normal speech while reading.

The expectancy of conventional sentence intonation was maximized by selecting high-frequency sentence components, such as "It's a," "That's a," "They can," commonly used in the introduction of high-frequency nouns and verbs in speech. These high-frequency initiating sentential strings were selected from Carterette's (1965) list of multiword units uttered by six-year-old children during a free discussion session. It is to be noted that children pronounced these word strings as if they were polysyllabic words. To each sentence initiator was attached a noun or a verb the children had previously learned in the list and matrix sections of the lessons, thus providing an opportunity to review these words.

After a number of pilot investigations focused on the timing of the learning events, the following experimental procedure proved to be most promising in achieving our objective.

1. Anticipation interval: a sentence appeared on a display device and the child was given 2 seconds in which to attempt an oral reading.

2. Reinforcement interval: the audio device played a reading of the sentence to the child.

3. Modeling interval: the child was given 2 seconds to repeat the reading of the sentence. For each new sentence the cycle was repeated.

In reinforcement terms, the child used self-evaluation to note any discrepancies between his reading and the machine's reading.

Each exercise in the "sentence initiator" section contained 25 sentences. Each initiator was presented approximately 5 to 10 times in a given lesson, for a total of 100 to 125 exposures in all the lessons. At this point, the sentence initiator was used in the story material.

The manner of presentation of the sentence initiators allowed the student to monitor his own production by comparing it with audio model. Additional monitoring of the student's performance in the sentence initiator material was accomplished by the proctors and by sample recordings made on a separate recording system.

3.2.2 Comprehension. Producing the appropriate verbalization when confronted with some orthography (decoding or word-attack skills) was a necessary component but not a complete definition of reading. An equal and ultimately more important aspect of reading may best be termed "comprehension." Although a great deal has been written about "reading comprehension," it is not at all clear what we mean by the term. The general approach in current reading materials and reading achievement tests is at the paragraph level and primarily employs practice in recall or identification of specific details and sequence of events, and in identifying the "main idea."

While using the standard techniques, we tried to look at the question at the sentence level. Although we make no claim of achieving a complete definition of the field, we advanced three propositions as necessary components for such a definition. To be sure a sentence was understood, it had to be demonstrated that there existed: (a) an appropriate set of semantic associations for each lexical item in the sentence; (b) an operational knowledge of syntax; and (c) the ability to identify the lexical items in the sentence which convey a given piece of information.

The next three sections of lesson material to be described were designed primarily to gather data pertinent to the above propositions. They are not, in the strict sense, teaching sections except that, as is the case throughout the lesson material, an overt correct response was required for each problem before the next one was presented. We do not feel that enough is known about comprehension to justify elaborate branching, remediation, and optimization routines. Hopefully, some indications of how we might develop reasonable teaching strategies in this area may be found in the data collected in the following sections of the lesson material.

Usage. A list of words was displayed on the scope. Auditory definitions were given one at a time and the student identified the word that matched each definition by a touch-probe response. The definitions were chosen with the following constraints:

1. If the word appeared in The Rainbow Dictionary (Wright, 1959)[1], all the meanings defined in that dictionary had to be used.

2. If the word did not appear in the Rainbow Dictionary, but appeared in the Thorndike-Barnhardt Beginning Dictionary (1964)[2], at least one of the definitions had to be used. The choice of usage was governed by the criteria of frequency and usefulness in story material.

3. If the word appeared in neither dictionary, it was not included in the usage section nor was it used in succeeding lesson materials (e.g., sentences, stories).

A strict dictionary-definition format was avoided in defining word items. To stress functional meanings, standard definitions were reconstructed as shown in the following example. For the word bat one dictionary definition is "a stout wooden stick or club, used to hit the ball in baseball, cricket,...." In the lesson materials this definition is reformulated by: "Touch and say the word that means something you might use to hit a baseball."

A correct response is reinforced by confirmation of the functional definition, "Yes, you hit a baseball with a bat." An incorrect reponse is corrected in a straightforward manner, "No, you hit a baseball with a ↓CA bat. Touch and say bat." Thus, for an initial correct response the definition was associated with the word twice. For an initial incorrect response, the definition was associated with the word three times, since the student received the reinforcing confirmation after his correct response. No branching or optimization routines were employed in the usage section.

Form class. As part of the concept of "comprehension" of a sentence, the child's basic understanding of English syntax had to be considered. One behavioral manifestation of a child's syntactic sophistication is his ability to group words into common form classes (nouns, verbs, modifiers, etc.). This section provides lesson materials that both assess and teach the form class characteristics for the words just presented in the matrix section.

The following type of problem was presented to the student:

Dan saw the	tan fat man run	hat.

Only one of the words in the column will make sense in the sentence. Touch and say the word that belongs in the sentence.

CA: Yes, Dan saw the tan hat.
Do the next one.
↓CA

WA: No, tan is the word that makes sense. Dan saw the tan hat.
Touch and say tan.

[1] Wright, W. W. The Rainbow Dictionary. Cleveland: World, 1959.

[2] Thorndike, E. L., & Barnhardt, C. L. (Eds.), Thorndike-Barnhardt Beginning Dictionary. New York: Scott Foresman, 1964.

The sentence was composed of words that are in the well-practiced reading vocabulary of the student (i.e., words already presented in previous or current lessons). The elements of the multiple-choice set included a word of the correct form class, but one semantically inappropriate; two words of the wrong form class; and of course, the correct word. A controlled variety of sentence types was employed, and the answer sets were distributed over all syntactic slots within each sentence type.

Response choices were categorized in rather broad terms as nouns, verbs, modifiers, and other. The response data were examined for systematic errors over a large number of items. The kinds of questions this data will answer are:

1. Are errors for various form classes in various sentence positions similarly distributed for a given student? for the general population?

2. How are response latencies affected by the syntactic and serial position of the response set within the sentence? by the sentence? by the sentence length?

Answers to these questions and others of a similarly general nature should provide information that will permit more systematic study of the relationship of sentence structure to reading instruction.

Inquiries. Individual words in sentences constituted unique and conversationally correct answers to questions. These questions took the interrogative form "Who ...?, What ...?, How ...?" The ability to select the word in a sentence that uniquely answered one of these questions demonstrated one form of reading comprehension at the level of the sentence. The set of exercises described in this section constituted an assessment of this reading comprehension ability.

John hit the ball.

Touch and say the word that answers the question.

RR 1 Who hit the ball?

CA: Yes, the word "John" tells us who hit the ball.
↓CA
WA: No, John tells us who hit the ball. Touch and say John.

RR 2 What did John hit?

CA: Yes, the word "ball" tell us what John hit.
↓CA
WA: No, ball tells us what John hit. Touch and say ball.

As in the form class section, each sentence was composed of words from the student's reading vocabulary. A wide variety of sentence structures were selected, beginning with simple subject-verb-object sentences and progressing to structures of increasing complexity. The data will be examined for effects caused by the different sentence types.

Stories the children read. When the children mastered a sufficient amount of vocabulary, including function and syntax words, stories read by the children were introduced into the reading lessons. These original children's stories were developed by skilled staff writers who understood children's literature. The principal problem encountered in this process was that of creating stories around a highly restricted vocabulary. Therefore the following criteria were used in preparing and editing these original stories: (a) variety of literary themes; (b) familiarity of the children with the thematic content and characters; (c) logical sequence of events; (d) simplicity of plot and characterization; (e) appropriateness of the restricted vocabulary; and (f) story length. These stories were first inserted in the lessons at Level IV.

The stories were like a story in a story book. The child read the story to himself. If he did not know a word, he was directed to touch the word, and the entire sentence in which the word appeared was read to him. Illustrations were used with the story as they were needed to help develop an understanding of the concepts presented. These illustrations were specified by the authors and prepared by the project's art staff.

After the child completed the story, he was questioned to determine his level of comprehension. The types of questions were divided into four main categories: (a) questions that dealt with direct recall of facts, such as identification of characters and the sequence of events; (b) generalizations about main ideas which related both characters and events within the story in which these characters and/or events were not presented in close contiguity; (c) inferential questions which required the child to relate information presented in the story to information stored in his memory about his own experience; and (d) subjective questions which included personal ratings and opinions of the stories.

The kinds of questions asked about each story were determined by its content, therefore, not all stories had exactly the same type of questions. Question types were carefully sequenced throughout the stories to provide equal representation. Four questions generally were asked about each story. Again the questions and the related stories represented an attempt by the project staff to collect appropriate information that would be helpful in formulating comprehension hypotheses. Any theoretical development in this area had to relate both the child's immediate information gathering ability and his ability to logically relate this new information with concepts stored in his memory system.

3.2.3. Games and Other Motivational Devices

Rhymes. Rhymes were sequenced into a lesson as a listening activity to help the child develop competency in the discrimination of the rhyming and alliterative sounds of words and to demonstrate to the child the rhythmic use of language. The selection of rhymes for each lesson was based upon the sound patterns found in the matrix section of the lesson.

Games. The games sequenced into each lesson primarily to encourage continued attention to the lesson materials were similar to those played in the classroom and used terminology common to game-like situations, such as baseball or bingo. In addition, each game was structured to reveal any developing linguistic competency on the part of the child. For example, one game centered on the child's ability to identify a given string of letters when presented in a concept-identification paradigm. The question of how children come to see orthographic commonalities is relatively unexplored, and the game was intended to provide some basic information. Moreover, the games gave the children added practice on the sequenced vocabulary.

As indicated earlier, all of these games were intended to provide the children with an intrinsic motivation to continue practicing much of the same material previously presented. Ordinarily the words found in the games were introduced in the preceding lesson. Again, it is to be noted that the responses in the game sections can be analyzed just as paired-associate items or as concept-identification items in more controlled psychological experimentation.

3.2.4. Review Lessons

Two types of review are to be found in the reading lessons. A continuous review is inherent in the learning materials which were sequentially introduced in a given lesson and subsequently incorporated in the activities of succeeding lessons. For example, words introduced in list and matrix exercises in Lesson N were reviewed in the sentence initiator and story materials of Lesson N + 1. A more conventional type of review was furnished also by review lessons, which appeared approximately every seventh lesson. Vocabulary and concepts previously introduced were re-presented, but in different formats.

The nature of the review lessons varied as the vocabulary and skills of the student progressed. In Level I, the review lessons consisted primarily of straightforward matrix review; that is, the words introduced in the preceding five to seven matrices were reordered and presented in new matrix formats. The review lessons of Level II focused primarily on the recently acquired vocabulary items, prepositions, and the inflectional concepts of the plural-s, third person singular-s, and the -ing suffix.

In Level III, the range of activities in the review lessons was considerably increased and basically furnished the format for review lessons in the succeeding levels. Exercises on phonetic discrimination, word meaning, form class, English word order, rhyming exercises, analysis and synthesis of words, picture-sentence comprehension, compound and polysyllabic words, and verb forms were included.

Lesson Production. An overall design of scope and sequence for the decoding aspect of the curriculum was developed during the first year of the project and was based on the psycholinguistic propositions stated above. The overall design was the primary responsibility of the principal investigator, the senior research associate, and the staff linguist. It must be emphasized, however, that at every stage in the development of the curriculum the intuitions, experience, and expertise of the entire staff played a major role.

A well-defined sequence of presentation of linguistic patterns was a necessary preliminary to actual lesson writing. The development of such a sequence, however, was a dynamic process which involved a complex interaction of study, deliberation, experimentation, and evaluation.

Within-level sequencing. Since the sounding matrix determines the monosyllabic patterns, the vocabulary available for each lesson and the number of lessons to be contained in each level, the next step in lesson writing, after the overall-sequence was established, was to generate and sequence the sounding matrices within a level. The responsibility for this task was usually assumed by a single writer, although in the larger levels two writers often worked as a team.

All possible words and nonsense words were generated for the level by permuting the consonants and consonant clusters about vowels under the constraint of the patterns and letters assigned to a given level. The resulting set of words and nonsense words was then sorted into matrices by a trial-and-error method. The goal was to produce an optimal set of matrices giving adequate practice for all the patterns. Each matrix conformed to the following specifications:

1. No matrix exceeded a size of 16 cells.

2. No matrix contained a ratio of nonsense to real words in excess of 40 per cent.

3. Socially unacceptable words were excluded.

4. Nonsense words which were misspellings of common monosyllabic words were excluded unless they formed highly productive syllables in polysyllabic words.

5. Non-English nonsense words were excluded.

An exhaustive treatment of the patterns was made in Levels I and II. In the later levels, however, adequate exposure and practice for each pattern was provided and an increasing proportion of the possible words for a given pattern was withheld from direct teaching in order to use the words as transfer items.

After the matrix-generating writer or team produced a reasonable set of matrices for a level, the result was reviewed by the entire staff and suggestions were made for improving the sequence. The matrix-sequencing process usually went through several iterations of trial and review before a consensus was reached and a set of matrices was approved for a level.

Lesson level. Once the sounding matrices were generated and sequenced for a given level the actual lesson writing began. Each lesson which contained a matrix is called a "standard lesson," and included many learning tasks and problem types. A discussion of the various standard problem blocks is found in the section headed "Curriculum Description." Each writer was responsible for the production of some set of problem blocks within a level. A balance was sought between the more mechanical blocks (e.g., matrix construction) and the more creative blocks (e.g., usage, form class, poems) for each writer's assignment.

Writing a lesson was quite different from writing a portion of an ordinary text book. It was more akin, perhaps, to writing a movie or TV script. Everything the student heard, saw, did had to be defined clearly for every minute spent at the terminal. Each display on the CRT had to be unambigously specified and desired changes in the display were cued precisely with the audio messages. Displays on the projector were sketched in sufficient detail for communication with the artists. The timing of projector displays was also specified clearly.

Although the branching logic, test criteria, optimization routines and within-lesson task sequence were determined in general by staff consensus, the lesson writer had to communicate all such information clearly to the curriculum programmers for each problem in every lesson. Lesson production forms were developed for all the standard problem types to minimize the amount of repetitive detail required of the writers and to insure uniform presentation of many of the learning tasks for experimental purposes.

Nonstandard lessons were those which presented nonrecurring or very infrequent learning tasks. The lesson which covered the comparative morphemes -er and -est was an example of a nonstandard lesson. Whether it was an entire lesson or a section of an otherwise standard lesson, the writer had to explicate all information for each problem without the benefit of forms--a tedious and time-consuming task.

Chiefly experienced primary teachers and graduate students in education made up the writing staff. It is difficult, however, to define clearly what is meant by the term "writing staff" since most of the writers had other responsibilities within the project, and nearly all members of the project staff, with the exception of the programmers and artists, made major contributions to the writing effort at one time or another. It is even more difficult to make a reasonable estimate of the man-hours required to write a lesson. The production rate for lesson material, including editing but excluding audio recording, art production and programming was on the order of 100 lessons a year which represents something in excess of 90 man-hours per lesson.

Editing. Editing the lesson materials was a vital and sensitive process in the production of the Stanford CAI Reading Curriculum. Vocabulary constraints imposed by the careful sequencing of patterns could not be violated, and the branching logic of each problem block had to be checked for consistency. The lesson editor was also responsible for the overall quality of the lesson material (i.e., interest and appropriateness of the sentences, poems and stories).

Several methods of organizing the editing process were tried during the early phases of the project, such as section sub-editing, and round-robin multiple editing. It was largely through these efforts to control and make manageable the extremely complex editorial requirements that the standardized formats were developed. The problem of vocabulary control became too difficult in the later levels to be met by the normal editorial procedures. A dictionary or word list was compiled which was stored in a computer and continuously updated. A dictionary look-up program was written which matched the displayed text of each lesson against the stored dictionary and printed out the words used in the lesson not found in the dictionary up to that point. The resulting printout was examined by the lesson editor to identify those words which were allowable transfer items. Corrections were made then in the lesson text to eliminate the remaining words detected by the computer program (i.e., those words not in the dictionary at that point in the pattern sequence and not usable under the rules for transfer items). A high degree of consistency and accuracy in vocabulary control was obtained by the above procedure.

3.3. Curriculum Implementation

After a lesson for a computer-assisted instructional course was written, many additional steps were necessary before the lesson was ready for use. The major steps in curriculum implementation were audio preparation, film preparation, and coding.

Audio production. The first step in producing audio tapes was to number individual audio messages. The coders numbered each message in the lesson books after the lessons received a final editing. The numbering of audio messages was necessary, since the coders referred to the messages only by number when coding the lessons. As the messages were numbered, an indicater [X] was placed at each point in the message where a display change on the projector or CRT had to be made in order to synchronize with the audio. These display changes most commonly involved the addition or deletion of an arrow or an underline to an existing display, hence the X's were referred to as emphasis indicators.

The messages were numbered in blocks of 50 to facilitate future editing or revisions. The message code number consisted of an alphabetic character followed by two digits and identified uniquely 1,300 messages for each lesson. In practice, the average lesson contained approximately 400 messages.

After the messages were numbered by the coders, the master narration tape was recorded on an Ampex PR-10 two-track tape recorder. The messages were recorded on the "A" channel using an LTV 1800 cardioid microphone. A constant 400-cycle tone was recorded on the "B" channel in conjunction with each message from a Hewlett-Packard 200 AB oscillator controlled by a tone key.

The requirements of the system, which will be discussed in detail in the section "Audio Compiler," specified that the 400-cycle tone had to be generated by depressing the key at least 0.25 seconds before the message was started and had to continue for at least 0.25 seconds after the message was finished. Further, the intermessage gap had to last a minimum of 3 seconds and no more than 10 seconds. Also, the emphasis indicator had to be signaled by a cessation of the tone for at least 0.5 seconds and no more than 1.5 seconds.

Practical consideration of audio consumption at the student terminals required that the above minimum specifications were followed as nearly as possible. The recording narrators were required to exhibit pleasant voice quality, clear enunciation, and good intonation patterns, and to develop considerable skill in the use of the tone key.

The master narration tapes were produced in a soundproof recording studio at Ventura Hall on the Stanford campus.

The master narration tape for each lesson was edited and corrected by the narrator immediately after recording. The tapes were then given a final edit to verify correctness of the messages, clarity of enunciation, proper tone signal overlap, and accuracy of the emphasis indicators. The rather elaborate and painstaking editorial procedure was a vital part of audio production, since correction of tapes was very difficult once they reached the audio assembly process.

Audio assembly. After the master narration tape received the final editing by the narrators, it was sent to the Brentwood Laboratory for generation of a master four-track machine tape. The first two tracks contained audio messages taken from the master narration tape, the third track was reserved for on-line student recording, and the fourth track contained the tape segment addresses.

A machine master was produced by a computer program which read the tone signals on the master narration tape, evaluated the length of a set of such signals, and recorded their associated verbal messages on the machine master using an optimal packing strategy. Figure 11 is a graphic example of "optimal packing."

Insert Figure 11 about here

Verbal messages of varying length were recorded on the two message tracks in a manner that maximized the number of messages per

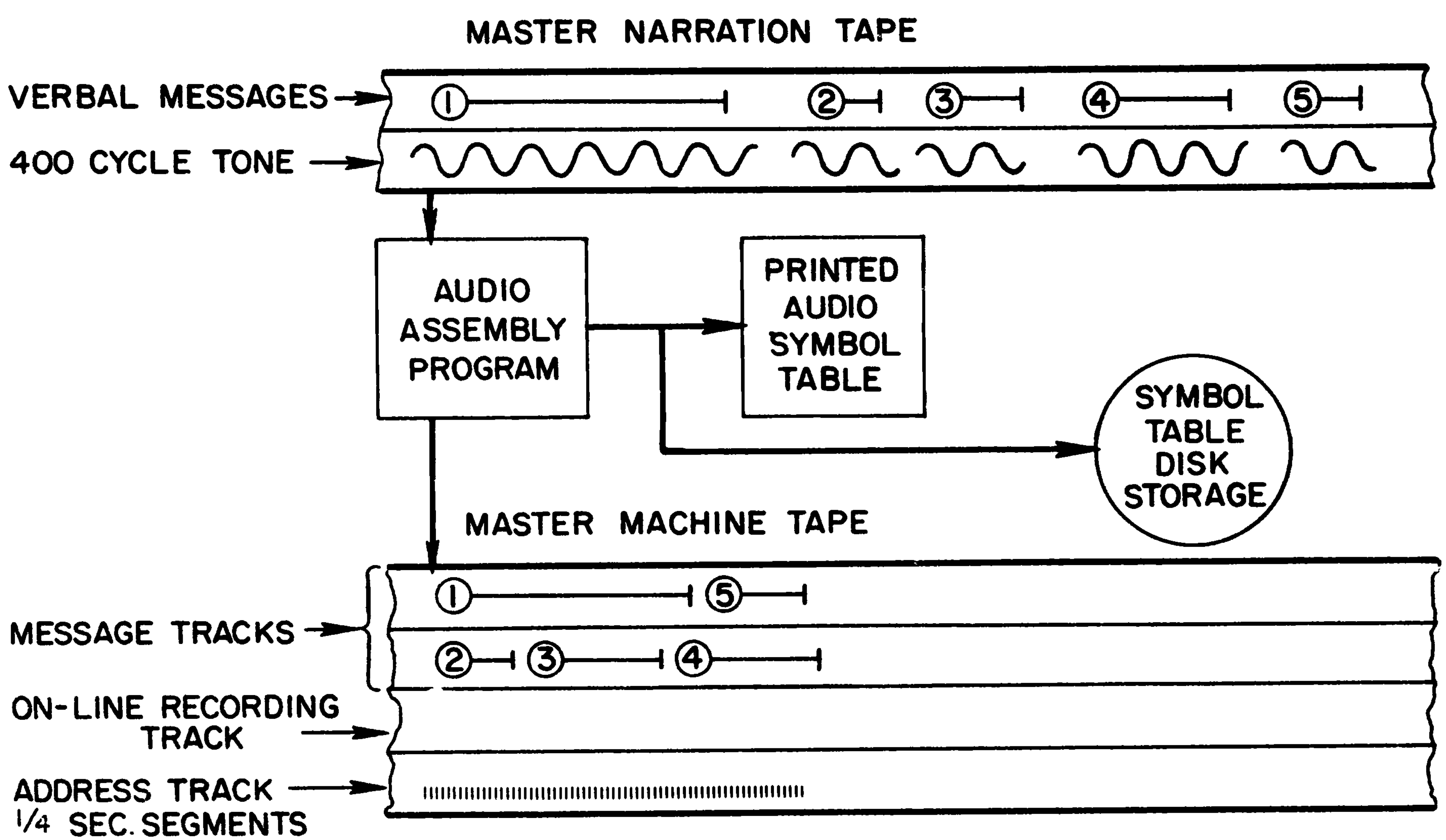

Fig. 11. Audio A[illegible]mbly Routine, Reading P[illegible]ect

unit length of tape and minimized the distance between any two messages. The latter condition also minimized the search time required for positioning any message.

The result of the optimal packing strategy was a non-sequential ordering of messages on the machine master. To control an otherwise chaotic condition, a table was generated concurrently with the recording of the messages which specified the location on the machine master by track and segment number of the beginning of each message, its sequential number on the master narration tape, and its length. This table, the Audio Symbol Table, was stored on the symbol table disk for each lesson. A printed audio symbol table was also produced for use by the programmers in the debugging process.

The complete process of producing a master machine tape and the associated tables, known as audio assembly, was performed during production hours, typically between 12:00 p.m. and 8:00 a.m., by a single computer operator.

Tape duplication. The terminal tapes were produced from the master machine tape on a Viking 235 Duplicator. Three duplicates were made simultaneously on the Viking at 7-1/2 inches per second. Tape duplication was under the control of a single technician, and the duplication time followed an intermittent demand schedule since the process was independent of the 1500 system.

The terminal tape requirements for each day were determined by the distribution of students over the lesson material. After all students completed a given lesson, all but three terminal tapes for that lesson were degaussed. The three remaining duplicates and the machine master were placed in storage. Three duplicates were found to be sufficient to act as a buffer to absorb new students and for demonstration purposes.

Art production. Production of the art work for the reading curriculum began with the lesson writers who, in the course of writing the lessons, specified the necessary illustrations. Illustrations were required for the word-list sections, some sentence analysis sections, and for all of the listening and reading stories and poems.

Techniques and media were dictated by the demands of high production and high quality. A felt tip marker used on two-ply bristol board, with occasional application of colored ink, chalk, paste-up, and tempera, was used for most of the plates. An additional factor in the choice of media and palette was the complex set of requirements of color photo-reproduction.

A serious attempt was made to include a balanced distribution of racial and ethnic figures in the pictorial illustrations as a reflection of the mixture of those elements in American society. The goal was to feature all racial and ethnic types as central figures engaged in interesting activities by means of artistically, socially honest, and appropriate drawing.

The illustrations were photographed in blocks of lessons at the Hospital Laboratory of the Stanford Photo Service with a 16mm movie camera and single-frame exposure. Correct sequence of illustrations was critical; therefore, the art editor, who originally assembled the plates, was on hand to assist the photographer at every shooting session. The plates were shot in blocks of lessons with nine blank frames left between blocks to minimize the difficulty of splicing if later corrections or additions were necessary.

A work print which was examined by the art editor was also produced by the processing laboratory. The work print was stepped through an IBM 1512 projector at the Brentwood Laboratory and was checked for proper sequence and acceptable color. The work print was returned to the processing laboratory after final approval by the art editor, and a release print was made. The release print, which contained pictures but no identification code, was combined, through a process known as A-B printing, with a code master to produce a master film. The master film was then used to produce the six terminal prints for debugging on the 1500 system. Mounted on self-threading, dust-proof cartridges, the six terminal prints were used, along with the audio tapes, for debugging coded lessons. When the debugging process was completed, a quantity of terminal prints was produced and mounted to assure sufficient films and reserves to accommodate the maximum number of students anticipated to be working at a level at any given time.

The majority of art work produced for the mathematics curriculum consisted of geometric figures drawn in ink line by technical illustrators or paste-ups of colored forms. Occasional drills were shown in story form and were illustrated by more complex colored illustrations in various media.

Palmer Films in San Francisco handled all the photography, processing and printing until the necessary number of films was produced for use in the Laboratory. The process of film handling generally corresponded to that for the reading group.

Coding. Before using the lessons in the CAI system, they were translated into a language understood by the computer. First, the lesson programmers coded the lessons in Coursewriter II, a CAI source language developed by IBM. A coded lesson consisted of a series of Coursewriter II commands which caused the computer to display and manipulate text and graphics on the CRT, position and display film in the projector, position and play audio messages, accept and evaluate keyboard and light-pen responses, update the performance record of each student, and implement the branching logic of the lesson flow by means of manipulating and referencing a set of switches and counters. A typical reading lesson required 9,000 Coursewriter II commands for its execution.

The audio messages and film images required for two sample reading problems, together with possible addresses on the audio tape and film strip, are shown in Table 6. What follows are the computer commands required to present the two problems described in Table 6, analyze the student responses, and record them on the data record. The

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Insert Table 6 about here

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left column lists actual commands to the computer controlling the instruction. (Labels L1, L2, etc., in the column on the far left indicate branching points.) On the right is an explanation of the results of the execution of these commands. The first problem is explained command by command; the second problem is explained only in outline.

Commands	Explanation
Pr	Problem: Prepares machine for beginning of new problem.
LD 0/S1	Load: Loads 0 into the error switch (S1). The role of switches and counters will be explained later.
FP F01	Film Position: Displays frame F01 (picture of a bag).
DT 5,18/bat/	Display Text: Displays "bat" on line 5, starting in column 18 on the CRT.
DT 7,18/bag/	Displays "bag" on line 7, starting in column 18 on the CRT.
DT 9,18/rat/	Displays "rat" on line 9, starting in column 18 on the CRT.
AUP A01	Audio Play: Plays audio message #A01. "Touch and say the word that goes with the picture."
L1 EP 30/ABCD1	Enter and Process: Activates the light pen; specifies the time limit (30 seconds) and the problem identifier (ABCD1) that will be placed in the data record along with all responses to this problem. If a response is made within the time limit, the computer skips from this command down to the CA (correct answer comparison) command. If no response is made within the time limit, the commands immediately following the EP command are executed.
AD 1/C4	Add: Adds 1 to the overtime counter (C4).
LD 1/S1	Load: Loads 1 into the error switch (S1).

TABLE 6

Audio Script and Film Images with Hypothetical Addresses, Reading Project

Audio information	
Address	Message
A01:	Touch and say the word that goes with the picture.
A02:	Good. Bag. Do the next one.
A03:	No.
A04:	The word that goes with the picture is bag. Touch and say bag.
A05:	Good. Card. Do the next one.
A06:	No.
A07:	The word that goes with the picture is card. Touch and say card.

Film strip	
Address	Picture
F01:	Picture of a bag.
F02:	Picture of a card.

Commands	Explanation
AUP A04	Audio Play: Plays message #A04. "The word that goes with the picture is tag. Touch and say bag."
DT 7,16/→/	Display Text: Displays "→" on line 7, column 16 (arrow pointing at "tag").
BR L1	Branch: Branches to command labeled L1. The computer will now do that command (EP) and continue from that point.
CA 1,7,3,18/C1	Correct Answer: Compares student response with the area-1 line high starting on line 7, 3 columns wide starting in column 18 on the CRT. If his response falls within this area, it will be recorded in the data with the answer identifier C1. When a correct answer has been made, the commands from here down to WA (wrong-answer comparison) are executed. Then the machine jumps ahead to the next PR. If the response does not fall in the correct area, the machine skips from this command down to the WA command.
BR L2/S1/1	Branch: Branches to command labeled L2 if the error switch (S1) is equal to 1.
AD 1/C1	Add: Adds 1 to the initial correct-answer counter (C1).
L2 AUP A02	Audio Play: Plays audio message #A02. "Good. Bag. Do the next one."
WA 1,5,3,18/W1 WA 1,9,3,18/W2	Wrong Answer: These two commands compare the student response with the areas of the two wrong answers (i.e., the area-1 line high starting on line 5, 3 columns wide starting in column 18, and the area-1 line high starting on line 9, 3 columns wide starting in column 18). If the response falls within one of these two areas, it will be recorded with the appropriate identifier (W1 or W2). When a defined wrong answer has been made, the commands from here down to UN (undefined answer) are executed. Then the computer goes back to the EP for this problem. If the response does not fall in one of the defined wrong-answer areas, the machine skips from this command down to the UN command.
AD 1/C2	Add: Adds 1 to the defined wrong-answer counter (C2).

Commands	Explanation
L3 LD 1/S1	Load: Loads 1 into the error switch (S1).
AUP A03	Audio Play: Plays message #A03. "No."
AUP A04	Audio Play: Plays message #A04. "The word that goes with the picture is 'bag.' Touch and say bag."
DT 7, 16/→/	Display Text: Displays "→" on line 7, column 16.
UN	Undefined Wrong Answer: If machine reaches this point in the program, the student has made neither a correct nor a defined wrong answer.
AD 1/C3	Add: Adds 1 to the undefined answer counter (C3).
BR L3	Branch: Branches to command labeled L3. (The same thing should be done for both UN and WA answers. This branch saves repeating the commands from L3 down to UN.)
PR	Prepares the machine for next (second) problem.
LD 0/S1	These commands prepare the display for the second problem.
FP F02	Notice the new film position and new words displayed.
DT 5,18/card/ DT 7,18/cart/ DT 9,18/hard/	The student was told to "do the next one" when he finished the last problem so he needed no audio message to begin this.
L4 EP 30/ABCD2	Light pen is activated.
AD 1/C4 LD 1/S1 AUP A07 DT 5,16/→/ BR L4	These commands are executed only if no response is made in the time limit of 30 seconds; otherwise, the machine skips to the CA command.
CA 1,5,4,18/C2	Compares response with correct-answer area.

Commands	Explanation
BR L5/S1/1 AD 1/C1 L5 AUP A05	1 is added to the initial correct-answer counter unless the error switch (S1) shows that an error has been made for this problem. The student is told he is correct and goes on to the next problem. These commands are executed only if a correct answer has been made.
WA 1,7,4,18/W3 WA 1,9,4,18/W4	Compare response with defined wrong answer.
AD 1/C2 L6 LD 1/S1 AUP A06 AUP A07 DT 5,16/→/	1 is added to the defined wrong-answer area and the error switch (S1) is loaded with 1 to show that an error has been made on this problem. The student is told he is wrong, is shown the correct answer, and is asked to touch it. These commands are executed only if a defined wrong answer has been made.
UN	An undefined response has been made if the machine reaches this command.
AD 1/C3 BR L6	1 is added to the undefined answer counter, and we branch up to give the same audio, etc., as is given for the defined wrong answer.

Thirty counters used to keep track of a student's performance were available to the lesson programmer. During the instructional flow, the current values of these counters were used to make branching decisions of what stimulus materials to present next. For example, if the correct-answer counter for a particular class of problems had a high value, the student branched ahead to more difficult topics; a low value branched him to remedial work. These counters contained any number from 0 to 32,767. They were normally set at zero at the beginning of a course and supplemented when desired. For example, counter 4 (C4) was used to record overtimes; each time the time limit was exceeded one was added to counter 4 (AD 1/C4).

Thirty-two switches in either the zero or one position were available to the instructor and kept track of previous events. For example, at the beginning of a problem, zero was loaded into S1 (the "error" switch), which meant no error had yet been made on that problem. If the student made an error on the problem, one was loaded into S1. If a correct answer was achieved on his second try, the command branched around, adding one to the initial correct-answer counter because the error switch (S1) was equal to one.

Many features of the CAI system are not demonstrated by the simplified example presented here, for the pattern of the problems may vary widely from this sample. At various points in a lesson, criteria may be set which, if not met, branch the student to remedial problems or call the proctor. Parts of the CRT display may be underlined or displayed in synchronization with the audio messages.

While a student was on the system, it was possible for him to complete as many as 5 or 10 problems per minute of the type shown above, providing a significant amount of coded lesson material for student use was not a major problem. Typically, reading program material was presented in blocks with problems similar in format but different in certain specific ways. The two example problems differ only in (a) film display; (b) word display; (c) problem identifier; (d) the three audio numbers; (e) row display of "→" (correct-answer row); (f) correct-answer area; and (g) correct-answer identifier. This string of code was defined once, given a two-letter name, and used later by giving a one-line macro command; the specifics which varied from problem to problem are called parameters.

The use of macros cut down greatly the effort required to present many different, but basically similar problems. For example, the two problems presented command by command above were presented in macro format:
Problem 1: CM PW]F01]bat]bag]rat]A01]ABCD1]A04]A02]A03]7]1,7,3,18]C1];
Problem 2: CM PW]F02]card]cart]hard]]ABCD2]A07]A05]A06]5]1,5,4,18]C2].
The command to call a macro was CM. PW was our two-character code for the macro involving a picture-to-word match. Notice that in problem 2 there was no introductory audio message; the "]]" indicated that this parameter was not to be filled in.

The macro capability of the source language had two distinct advantages over code written command by command. The first was ease and speed of coding. The call of one macro was obviously easier than writing the comparable string of code. The second advantage was accuracy. Not only were coding errors drastically curtailed, but if the original macro was defective or needed to be changed, every occurrence of it in the lesson coding could be corrected by modifying the original macro; in general, the code stayed as it was. The more standard the problem format, the more valuable the macro capability became. Apart from a few nonstandard instructional audio messages and display items, approximately 90 to 95 per cent of all the reading curriculum was programmed using roughly 110 basic macros.

In the 1967-68 school year, a major effort was made to move the students through the lessons at a faster rate. The lesson code was revised to speed up two areas that proved hindrances to student progress: restart points had been placed too far apart, and audio responses had been too slow. Revisions of the lesson code progressed in two stages. For Level II, interim macros were written to adjust the distance between restart points and to minimize audio delay by prepositioning for a CA audio while the student responded. A second and final set of macros was written for use in Level III and beyond. Revisions were incorporated in the interim macros, and also replaced the CA audio with a smiling face on the CRT. The word "no" in the WA audio was also replaced by a crying face. The use of smiling and crying faces positioned the audio to the next instructional message, while the student received visual reinforcement or feedback.

The final step in translating the lesson material to a form usable in the computer was the lesson assembly process. A series of machine-language programs read in the coded lessons, expanded the macros, translated the audio code to actual tape addresses from the audio assembly table, and finally read out the assembled lesson translated into binary code onto a disk.

The final editing step was the debugging process that was carried out at the student terminals by making all correct and all incorrect responses for each lesson. Errors left uncorrected from any stage in the production processes were detected as they might be seen by a student. Corrections were made, and the lesson checked again in a similar manner. This iterative debugging process proved vital for the assurance that the student would not suffer from human error inherent in the complex process of lesson production.

Chapter 4

Findings and Analysis

4.1. Student Progress in Mathematics

A primary objective of CAI was to accommodate individual differences by providing a variety of paths through the curriculum, such as allowing the faster student to proceed to new problems as soon as he exhibited mastery of the old, while giving the slower learner remedial material if necessary to help him gain mastery of a new concept. Each child worked independently of the others. An examination of the progress of the students and their spread over the lesson material as shown in the following sections gives a partial evaluation of the effectiveness of the Stanford-Brentwood program of computer-assisted instruction.

Mathematics progress, November-December, 1966. On November 7, a regular schedule was established for children in the terminal room. Groups continued to be divided into two 10-minute periods, with seven proctors each assigned to listen with one child. By November 9, most children started their lessons without help from a proctor, and by November 14, most students were working in Books 2 and 3. In the month of November, the children's work on-line was interrupted by three major systems breakdowns; i.e., one group on November 7, all groups on November 10, and two groups on November 30 were unable to work on the machines. With the exception of the above groups, children worked on the machines for a total of 23 days up to December 16. The progress of the children in the programmed lessons is shown in Table 7.

Insert Table 7 about here

Mathematics progress, January-March, 1967. By January 1, most children were doing lessons on numeral recognition, counting and N-notation. A few children were introduced to addition (Book 7), and a few were still finishing the lessons on set union. By the end of March, most children finished the introduction to addition, lessons on sequences, the introduction to number line, sums through nine, and lessons on open and closed figures, concave and convex figures, and linear measure. They began problems which required the student to supply the missing addends. A few children finished the missing addend problems, as well as some lessons on number words. The progress of the children through the programmed curriculum is shown in Table 8.

Insert Table 8 about here

TABLE 7

Mathematics Progress, November-December, 1966

	Oct. 24 -Oct. 29	Oct. 31 -Nov. 4	Nov. 7 -Nov. 11	Nov. 14* -Nov. 18	Nov. 21 -Nov. 25	Nov. 28 -Dec. 2	Dec. 5 -Dec. 9	Dec. 12 -Dec. 16
Book 1	49	17	4	4				
Book 2A		2	39	39	8		1**	
Book 2B		6	6	6	20	4		
Book 3A					21	20	7	1
Book 3B						17	14	4
Book 4						8	18	11
Book 5							8	23
Book 6A							2	6
Book 6B								4
Book 6C								1

*During the week of Brentwood Parent Conferences (November 14-18) no children came to the laboratory for mathematics lessons.

**This child entered school on December 6.

TABLE 8

Student Progress in Programmed Mathematics Curriculum

	Jan 3-6	Jan 9-13	Jan 16-20[1]	Jan 23-27	Jan 30-Feb 3	Feb 6-10	Feb 13-17	Mar 20-24	Feb 27-Mar 3	Mar 6-10	Mar 13-17	Mar 20-24[2]	Mar 27-31
Book 4	4												
Book 5	13	5	1										
Book 6A	17	6	5	5	1								
Book 6B	9	9	3	1	4	2							
Book 6C	1	12	9	6	5	5	4	4	4	4	4	4	4
Book 7A	4	11	15	14	3	5	5	4	4	4	4	4	4
Book 7B	2	2	10	9	14	5	5	3	3	3	3	3	3
Book 8		2	3	10	12	11	4	5	1	1	1	1	1
Book 9A		3		1	4	9	11	2	4	1			
Book 10			4	2	5	6	9	11	3	2			
Book 9B				2	2	7	4	9	5	2	2	2	
Book 14A							8	12	20	22	12	12	10
Book 14B									6	2	10	10	2
Book 15A										6	6	6	12
Book 15B										3	7	7	7
Book 16A											1	1	7

1. One student left the school; one new student was enrolled (starting in Book 6).

2. Spring vacation, March 20 - March 24.

Mathematics progress, April-June, 1967. During the period from April 1 to June 24, most of the children were doing programmed lessons on addition and subtraction to 10, and some progressed through sums greater than 10. Other topics included counting dimes and pennies as an introduction to the numbers from 10 to 20, and as readiness for the study of place value; number words zero through ten; one-half of an object; measuring isolated line segments and sides of polygons; recognition of similar figures in various sizes and positions; and concave figures. Table 9 shows the number of children working in each book during a given week. Those children who had advanced farthest by the end of the year had done few remedial lessons during the entire year, while those students who completed the fewest number of books spent a great deal of time on remedial work.

Insert Table 9 about here

Mathematics progress, July-September, 1967. On September 20, the students began the programmed lessons. By September 29, after eight days of CAI instruction, the fastest child had completed 5-1/2 books (62 lessons), while the slowest child had completed 2 books (25 lessons).

Mathematics progress, October-December, 1967. The children's progress through the programmed curriculum is shown in Table 10. As of September 29, the last day of the preceding quarter, the spread of the children was from Book 1 through Book 5 after eight days on-line. At the end of the quarter, the spread was from Book 6 through Book 19.

Insert Table 10 about here

The progress of the students through the curriculum was one indicator of student achievement; another was the proportion of problems to which students responded correctly. Table 11 shows the number of children whose achievement for a given week fell within the indicated range of percentage correct.

Insert Table 11 about here

Mathematics progress, January-March, 1968. By the end of March, 73 children worked on-line on the mathematics curriculum. Where the spread of the children at the end of the preceding quarter was from Book 6 through Book 19, at the end of the quarter the spread was from

TABLE 9

Number of Children in each Book of Programmed Mathematics Curriculum Shown by Weeks

Book	April 3-7	April 10-14	April 17-21	April 24-28	May 1-5	May 8-12	May 15-19	May 22-26	May 29-June 2	June 5-9	June 9-1
6C	3	1	1								
7A	4	1									
7B	2	2	2	1	1						
8	1	2	2	2*		1	1	1	1		
9A	2	3	2	3	1						
10	1	1	3	5		1				1	1
9B		1		1	4	1					
14A		1	2	2	4	1	1				
14B	1				1	6	3				
15A	6	1			1						
15B	4		1			1	1				
16	14	7	1		2		5	5	2	1	
17A	6	6	8	7	1	3	1	5	4	4	4
17B	6	20	8	5	2		2	1	3	3	3
18A		4	8	11	6**	2	2	2	3	2	1
18C			12	7	5	5		5	1	1	2
18B				8	14	6	7	3	5	2	2
19A					4	8	4	4	3	3	3
19B					5	8	4		2	3	1
20A					1	4	6	13	7	3	4
20B					1	5	9	6	5	7	8
21A						1	2	1	1	1	1
21B							5	5	5	1	1
22A								2	6	6	
22B									4	4	9
22C										2	1
23A										1	2
23B										4	1
24A										1	4
24B										2	2
25A											
25B											2

* Two children enrolled, started in Book 8.
** One child enrolled, started in Book 18A.

TABLE 10

Number of Children Completing a Book, Mathematics Curriculum

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Oct 2-6	1	13	40	26	6	1													
Oct 9-13		2	8	26	28	8	3	1											
Oct 16-20	1		8	4	12	15	2	2	1	1									
Oct 23-27		1		10	8	22	19	9	4	3	1								
Oct 30-Nov 3			1	5	9	7	15	9	7	3	2	1							
Nov 6-10				2	5	5	9	14	10	4	4	3	2	2					
*Nov 13-17				1	6	2	1	4	3	4	1								
**Nov 20-22						4	3	5	2	5	5	4	2		2				
Nov 27-Dec 1					1	4	6	2	15	7	7	9	5	2		1			
Dec 4-8						3	3	5	7	12	6	2	5	5	3	1	1		
Dec 11-14						2	3	1	3	7	5	5	7	3	5	2	2	2	1

*Three groups were not on-line at all this week because of parent conferences.

**Thanksgiving week, on-line three days.

TABLE 11

Distribution of Children in Mathematics Curriculum
According to Percentage Correct for the Week

Week of:	60% and below	61-65%	66-70%	71-75%	76-80%	81-85%	86-90%	91-95%	96-100 %
Sept 20-22	0	0	0	1	4	8	18	19	19
Sept 25-29	0	1	1	0	4	11	28	21	5
Oct 2-6	0	1	0	4	12	17	21	17	0
Oct 9-13	1	5	3	8	13	16	19	7	0
Oct 16-20	0	0	5	4	16	20	19	7	1
Oct 23-27	2	1	2	10	17	13	18	13	0
Oct 30-Nov 3	2	2	4	8	9	19	16	13	2
Nov 6-10	3	1	2	7	13	15	15	17	2
*Nov 13-17	1	2	1	6	6	5	5	5	0
Nov 20-22	3	2	2	4	11	17	17	13	3
**Nov 27-Dec 1	1	0	0	10	9	14	22	16	1
Dec 4-8	0	1	1	7	12	13	19	17	3
Dec 11-14	1	3	2	14	7	15	14	19	1

*Only children in Groups II and III received programmed material.

**Data lost for Nov. 30.

Book 11 through Book 35. Table 12 shows the number of children whose achievement for the week fell within the indicated range of percentage correct.

Insert Table 12 about here

4.2. Student Progress in Reading

Reading progress, November-December, 1966. As previously stated, the reading curriculum was organized around a main line or core of problems and exercises for which each student had to exhibit some degree of competency. The lessons averaged approximately 100 to 125 main-line problems each, excluding remedial loops, corrections, optimization routines, and accelerated branchings. At the beginning of Christmas vacation, the maximum number of sessions for any child on the system was 24, disregarding illnesses, school vacations, and terminal and system failures. This amounted to eight hours of instruction at the response terminal. The spread between the slowest and fastest student at the beginning of the Christmas vacation was 600 main-line problems after eight hours of instruction. Table 13 indicates the distribution of the students.

Insert Table 13 about here

Reading progress, January-March, 1967. The range of distribution of the students over the lessons continued to increase. The range was eight lessons at the beginning of January and 25 lessons at the end of March as shown by Table 14. The range is not easy to interpret since it reflects demographic movement in the student population. Four students transferred out and four transferred in. A more accurate range

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Insert Table 14 about here

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of the distibution is given in terms of the median and inter-decile range, shown in Figure 12. The latter increased from three lessons at the beginning to 14 lessons at the end of the period.

Insert Figure 12 about here

TABLE 12

Distribution of Children in Mathematics Curriculum According to Percentage Correct for the Week

Week of:	60 and below	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan 2-5	1	1		6	18	13	14	17	
Jan 8-12	5	1	3	8	5	16	16	12	5
Jan 15-16, 18-19	9	1	5	1	7	9	19	7	7
Jan 22-26	3	2	3	3	11	16	20	12	2
Jan 29-Feb 2		3	4	2	13	15	19	12	5
Feb 5-9	2	5	4	4	12	12	21	11	3
Feb 13-16	2	1	2	6	9	13	18	17	5
Feb 19-21, 23	1		3	11	6	16	22	13	3
Feb 26-Mar 1	2	2		6	7	18	17	16	6
Mar 4-8	4	1	4	4	6	12	20	19	5
Mar 11-15			2	4	8	17	25	15	1
Mar 18-22		2		4	5	23	25	12	3
Mar 25-29		2	1	1	4	20	24	16	3

TABLE 13

Student Distribution in Brentwood Reading Curriculum
November to December, 1966

		November 2	9	16	23	30	December 7	14 -	-16
Introductory Lessons	A	51							
	B		33	7					
	C		18	12	3	1			
Level 1	1			31	37	21	6	1	1
	2				10	25	34	26	19
	3					3	6	15	13
	4						3	4	13
	5						1	3	0
	6							1	3
	7								1
	8								
	9								
	10								
	11								
	12								
	13								

TABLE 14

Weekly Distribution of Students over Reading Lessons

Lesson Number	Date	1/4	1/11	1/18	1/25	2/1	2/8	2/15	2/22	3/1	3/8	3/15	3/29
I	1	1	1	0	0	0	2*	2*	0	0	0	0	0
	2	5	4	1	1	0	0	0	3*	3*	2*	2*	1
	3	25	13	7	4	4	2	0	0	0	0	0	0
	4	14	12	12	6	3	3	5	4	2	1*	0	0
	5	1	13	11	16	11	7	5	1	3	4	4	0
	6	2	3	10	4	8	9	4	5	1	1	2	5
	7	1	0	4	7	9	9	8	6	5	3	1	1
	8	0	1	0	6	2	5	6	6	8	4	1	1
	9	1	2	0	1	5	2	8	9	6	12	8	4
	10		1	2	0	3	4	3	5	9	4	9	7
	11			2	4	0	4	1	1	2	4	1	5
	12					1	0	5	3	2	3	6	5
	13					3	0	0	2	2	4	2	3
II	1						1	0	2	3	1	2	2
	2						3	0	1	2	1	3	2
	3							4	0	0	2	1	2
	4								0	0	2	1	2
	5								4	3	0	3	1
	6									1	1	1	4
	7										2	2	1
	8										0	1	0
	9.1										1	0	2
	9.2											1	1
	10												0
	11												1
	12												
Total Number of Students		50	50	49	49	49	51	51	52	52	52	51	50

*New Students

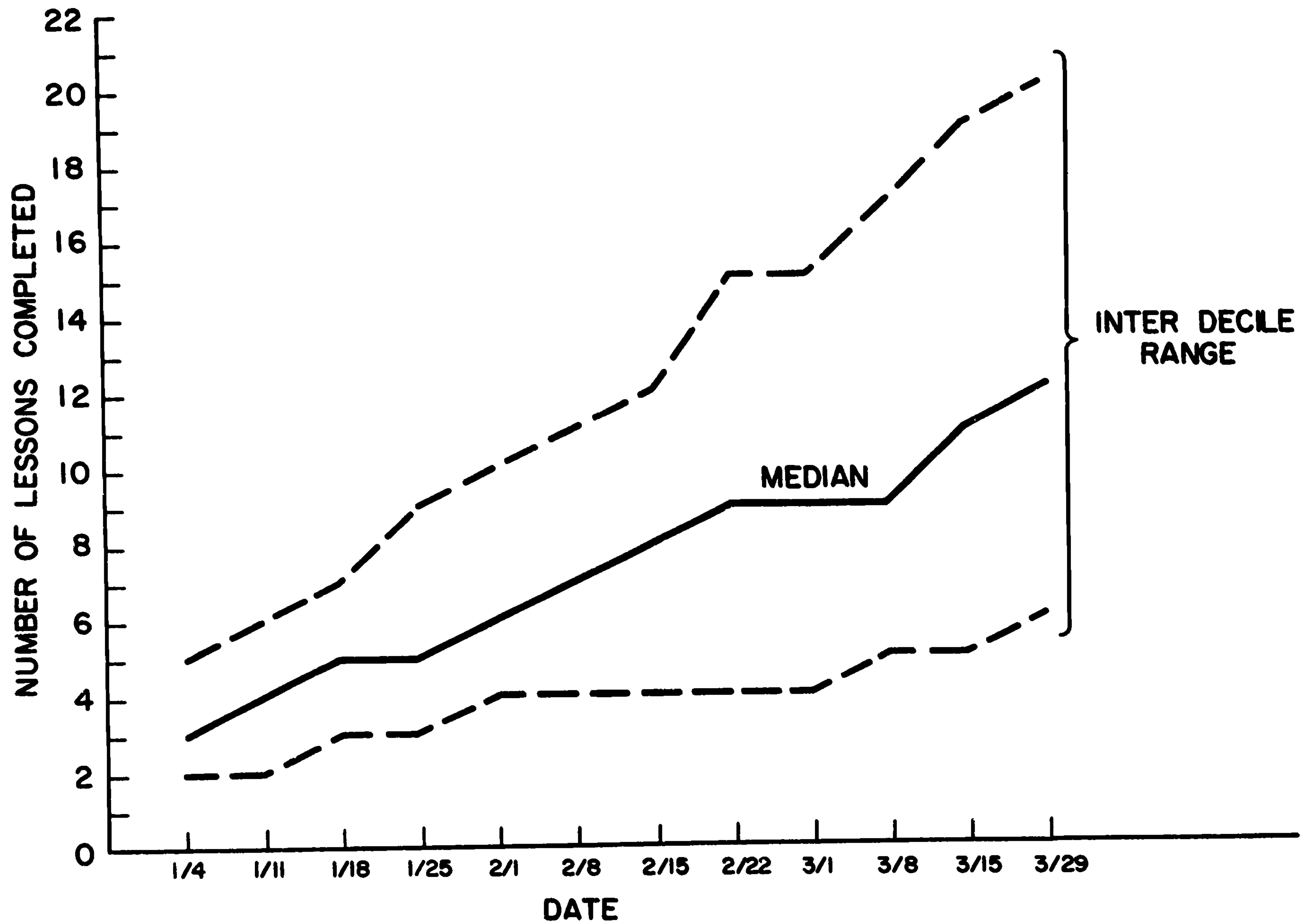

Fig. 12. Cumulative Number of Reading Lessons Completed Each Week for Current Reporting Period

Figure 13 indicates a rate-of-progress curve, plotted for the fastest and slowest students in the original population. The position of the student in the lesson material was plotted against the cumulative number of sessions the student had been at the terminal. The curves indicated that, at least for this period, the rate of progress for the two extreme subjects was essentially linear; the curves differed only in slope.

Insert Figure 13 about here

Reading progress, April-June, 1967. Thirteen remedial reading students from two second-grade classrooms were brought in the system on a daily basis during the period. They adapted quickly to the environment and their progress was satisfactory. The classroom teachers reported an increase in interest and application to classroom reading instruction by the students involved in the program.

A graph of the cumulative rate of progress for the remedial second-grade students after eight weeks of instruction is compared in Figure 14 with that of the regular first-grade students at the end of their first eight weeks of instruction. The range of the second-grade remedial students was from 58 to 131 main-line problems per hour with the median at 104. It is interesting to note that the bottom of the second-grade remedial distribution falls just under the median of the first-grade distribution.

Insert Figure 14 about here

Figure 15 shows the number of main-line problems completed each week by the fastest, slowest, and median student.

Insert Figure 15 about here

The year ended with a difference between the fastest and slowest student of 4,125 problems completed. The inter-quartile range was 1,375 problems, and the median student completed 2,625 main-line problems. The range in rate of progress was between 35 problems per hour for the slowest student to 170 main-line problems per hour for the fastest student. The inter-quartile range was 45 to 110 with the median at 75 problems per hour.

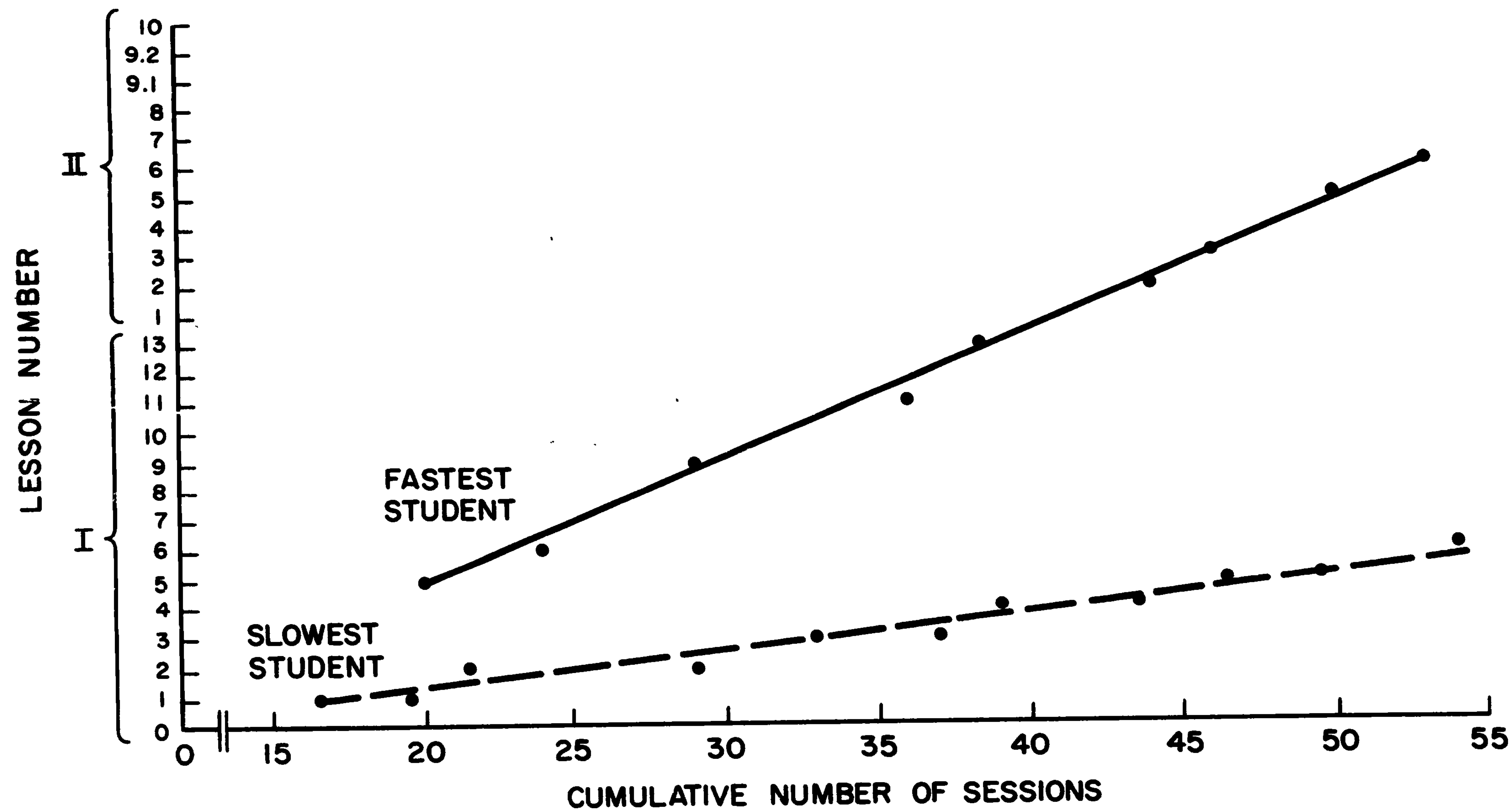

Fig. 13. Position in Reading Curriculum by Week plotted against Cumulative Number of Sessions on System for Fastest and Slowest Student in Original Student Population

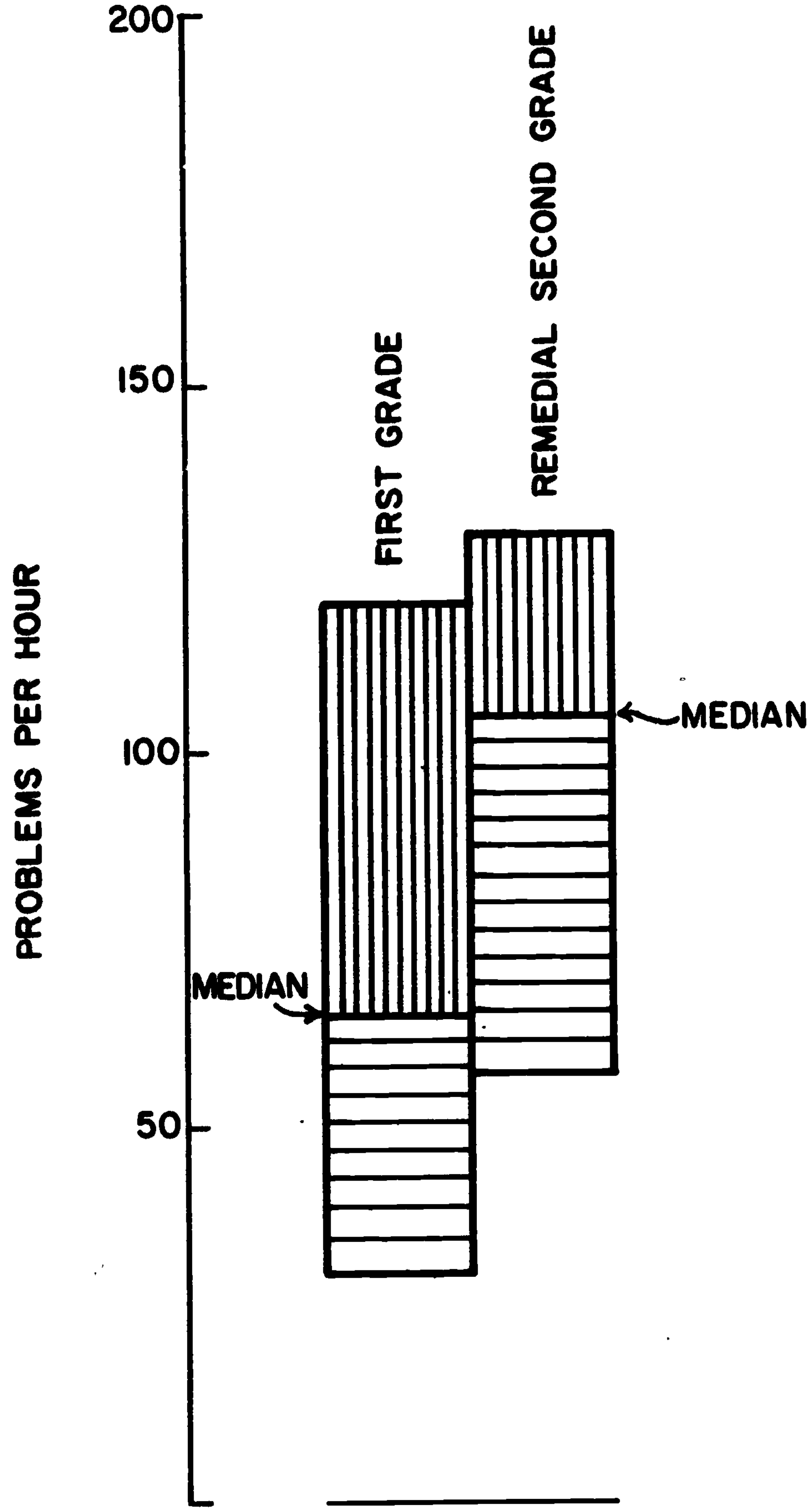

Fig. 14. Comparison of the Distribution of Rate of Progress of First-grade and Remedial Second-grade Students after Eight Weeks of CAI Reading Instruction

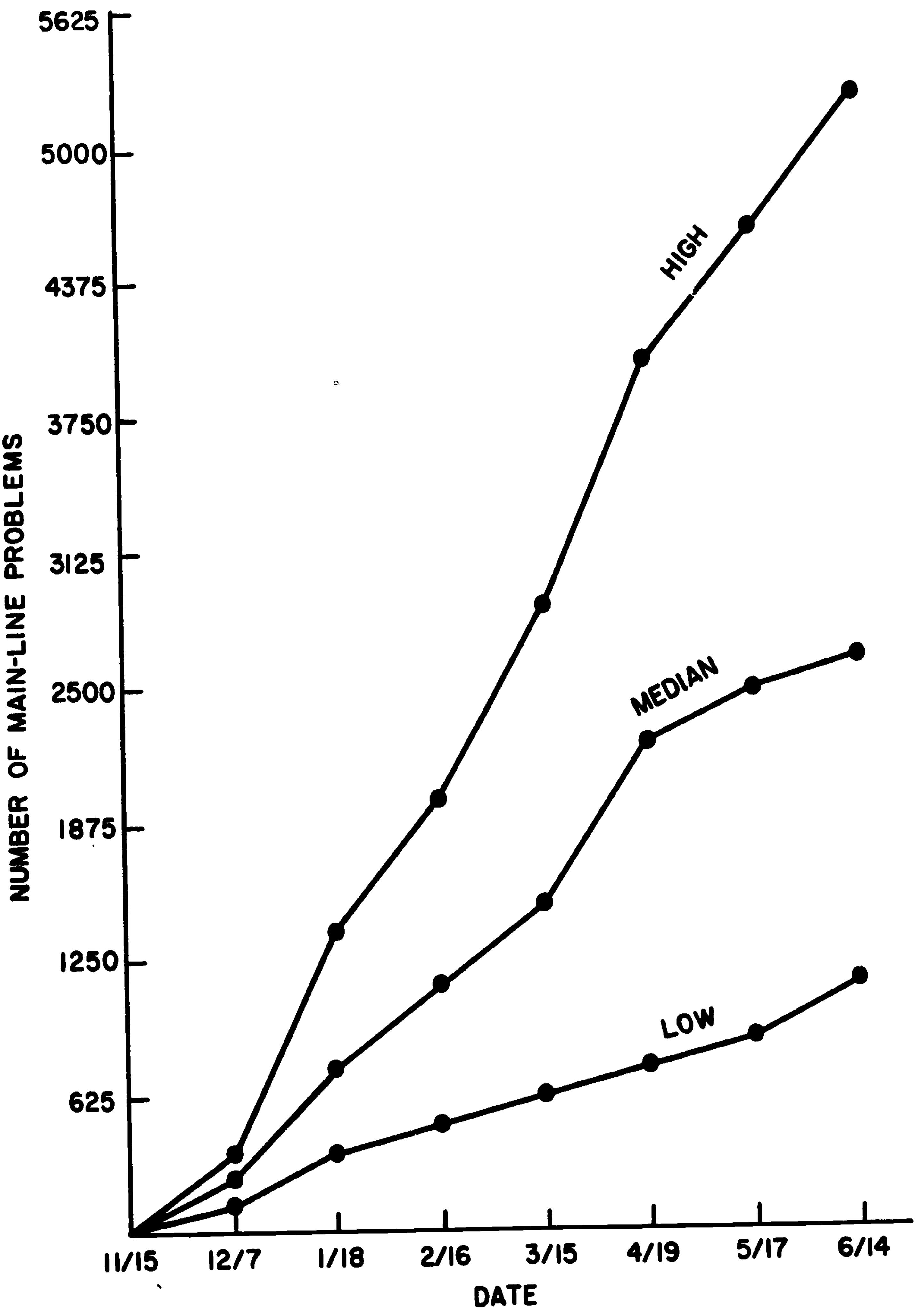

Fig. 15. Number of Main-line Reading Problems Completed Each Week by Fastest, Slowest, and Median Students

Reading progress, July-September, 1967. On September 20, the children began work on Days 1 and 2 with the introductory lessons. On September 25, they began Day 3, which consisted of the revised letter teaching lessons. On September 29, after the first week of instruction, the students were distributed as follows:

Lesson	Number of Students
Day 3	42
I-01	24
I-02	10
I-03	3
	79

Reading progress, October-December, 1967. On December 15, 76 first-grade students continued to receive computer-assisted instruction in reading. The method of presenting the curriculum was modified and these modifications substantially increased the students' rate of progress through the curriculum. Table 15 indicates the number of students in each lesson at the end of the third through eleventh weeks.

Insert Table 15 about here

By the third week, this year's most advanced student was three lessons ahead of last year's students; by the tenth week he had covered twice as many lessons.

Reading progress, January-March, 1968. On March 29, 80 first graders worked on the curriculum in addition to 7 remedial fourth graders who began work on March 13. By the end of the thirteenth week, this year's fastest student had completed 21 lessons more than last year's fastest student; by the end of the twenty-fifth week, he had completed 23 lessons more. Table 16 indicates the number of students in each lesson at the end of the thirteenth through the twenty-fifth weeks. The remedial fourth graders were excluded from the table.

Insert Table 16 about here

The underlined figure in each column represents the maximum progress by the fastest student during that same week last year.

Summary of student progress in reading and mathematics. The increasing spread of the students over both the mathematics and reading curricula indicated that at least some of the individual differences in the learning characteristics of the student populations were accommodated in the curriculum. The faster students quickly proceeded through material which they mastered, and the slower students took a

TABLE 15

Weekly Distribution of Students over Reading Lessons
(October - December)

Week Number	1	2	3	4	5	6	7	8	9	10	11
Number of Students			80	83	84	72[a]	72[a]	72	70	74	75
Letters-I			14	9	8	0	0	0	0	0	1
1-1			17	17	8	2	1	1	2	2	0
1-2			17	12	14	10	9	4	4	5	4
1-3			14	17	21	20	18	20	15	10	11
1-4			9	6	3	6	7	6	8	7	4
1-5			2	8	5	3	5	5	6	10	6
Letters-II			7	2	1	2	1	2	1	0	2
1-6				2	5	3	4	1	2	4	7
1-7				3	8	5	4	5	2	4	3
1-8				3	0	4	1	3	3	2	5
1-9				3	2	4	7	4	4	1	2
1-10				1	3	2	2	4	2	4	2
1-11					3	0	1	2	1	1	0
1-12					2	3	2	4	5	4	4
1-13					1	2	0	1	4	3	4
Letters-III						1	0	1	0	0	0
2-1						1	3	1	0	2	1
2-2						2	2	2	3	4	2
2-3							1	0	1	0	3
2-4							2	1	1	0	2
2-5								2	0	3	1
2-6								2	1	2	0
2-7								1	4	0	4
2-8									0	1	1
2.91									1	0	0
2.92										4	0
2-10										0	1
2-11										1	3
2-12											1
2-13											0
2-14											0
2-15											1

[a]Records on two students are missing.

TABLE 16

Weekly Distribution of Students over Reading Lessons
(January 2 - March 29)

Week Number	13	14	15	16	17	18	19	20	21	22	23	24	25
Number of Students	77	78	77	75	75	78	77	77	78	79	80	80	80
Lesson Number													
Letters-1	6	2	1	0	0	0	0	0	1	0	1	0	1
I-1	1	3	2	0	0	4	3	1	1	2	2	2	2
2	0	1	3	4	1	1	2	2	1	2	3	2	0
3	9	8	8	1	3	2	0	2	3	1	0	1	2
4	3	3	1	7	6	4	8	3	2	2	2	1	1
5	8	8	7	6	4	3	3	5	3	2	3	4	3
Letters-2	0	0	2	0	2	2	0	2	1	0	0	0	1
6	2	2	2	3	3	5	3	3	4	4	3	0	0
7	9	7	8	11	12	12	11	3	5	4	3	4	2
8	3	4	4	1	1	1	2	11	3	3	3	3	2
9	3	2	2	4	3	1	1	2	11	9	3	2	3
10	4	5	1	1	2	2	2	0	1	6	9	7	3
11	0	2	4	2	2	1	1	3	0	0	4	3	3
12	2	3	5	4	2	5	4	2	3	1	3	6	7
13	0	0	0	3	5	1	3	3	3	2	0	2	5
Letters-3	0	0	0	0	0	0	0	2	0	3	0	0	1
II-1	3	1	0	1	0	2	0	0	2	1	3	1	0
2	2	3	2	0	2	3	5	2	0	2	3	1	3
3	5	2	1	2	0	1	0	2	0	1	1	3	0
4	1	2	1	0	1	1	0	0	3	0	1	2	2
5	1	4	5	3	1	0	1	0	2	3	0	0	2
6	1	0	2	1	0	1	1	1	0	1	1	2	1
7	0	1	2	6	6	5	6	3	1	1	4	1	2
8	1	0	0	1	3	2	0	2	2	1	0	3	1
9.1	2	0	0	0	0	0	2	2	1	0	0	1	3
9.2	0	3	0	0	2	3	1	1	3	3	1	0	
10	3	1	3	0	0	2	2	4	2	4	5	2	0

TABLE 16 (cont.)

	Week Number	13	14	15	16	17	18	19	20	21	22	23	24	25
	Number of Students	77	78	77	75	75	78	77	77	78	79	80	80	80
Lesson Number	11	2	1	1	1	0	0	1	0	2	0	1	1	1
	12	0	2	1	3	0	0	1	0	2	1	1	2	1
	13	0	1	0	0	1	0	0	0	0	2	0	2	1
	14	0	0	3	1	2	0	0	2	0	2	2	0	3
	15	1	0	0	0	2	2	0	0	1	0	3	3	1
	16	0	0	0	2	0	1	2	0	1	1	0	1	0
	17	2	0	0	1	1	0	0	0	0	0	0	0	0
	18	1	2	0	0	0	0	1	1	0	0	0	0	1
	19	0	0	0	0	0	0	0	0	0	0	0	0	0
	III-1	1	2	1	0	1	3	0	1	1	1	1	2	3
	2	0	1	0	0	1	0	2	1	0	0	1	0	2
	3	0	1	2	0	0	0	1	0	2	1	0	0	0
	4	1	0	2	1	0	2	0	2	0	1	1	2	0
	5		1	0	2	0	0	0	1	0	1	1	1	0
	6			0	1	0	0	2	0	2	0	1	0	2
	7			1	0	0	0	0	0	0	0	0	1	0
	8				1	1	0	0	0	1	0	0	0	1
	9				0	2	0	0	2	0	3	0	1	1
	10				0	1	1	0	0	0	0	0	0	0
	11				1	1	3	0	0	0	0	2	0	1
	12					1	1	4	0	2	0	1	1	0
	13						1	1	2	0	2	0	2	0
	14							0	3	0	0	1	0	1
	15							1	0	2	0	1	0	2
	16								0	1	2	0	1	0
	17								1	2	0	1	0	0

TABLE 16 (cont.)

Week Number	13	14	15	16	17	18	19	20	21	22	23	24	25
Number of Students	77	78	77	75	75	78	77	77	78	79	80	80	80
Lesson Number													
18									0	1	2	3	1
19									1	2	0	0	0
20										0	2	1	2
21										0	0	0	0
22										1	0	0	1
23											1	2	0
IV-1												0	3
2												0	0
3												1	0
4													0
5													1

different path, receiving remedial material. Essentially, no two students followed an identical path. Computer-assisted instruction does appear to permit students to advance at their own rate of progress.

4.3. Data Analysis in Mathematics

Testing program. The testing program for the Brentwood first graders consisted of the Individual Stanford Binet I.Q., short form administered in the fall of 1966 and the Stanford Achievement Test, Primary I Battery, Form W administered the following spring.

The tests were administered to 100 students. Half of these students, the control group, did not participate in the computer-assisted mathematics program; the other half of the students, the experimental group, participated in the mathematics program for the 1966-67 school year.

Table 17 shows average SAT scores, in terms of grade equivalence, and the average I.Q. for the control and experimental groups. Data

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Insert Table 17 about here

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are also presented for each of these groups divided into low and average groups as a function of I.Q. There was no significant difference in I.Q. between the experimental and control students for any of the three possible comparisons. The t tests on the SAT scores were significant only for the low I.Q. group with the subjects in the experimental group performing better than the subjects in the control group.

Within the average I.Q. group, the experimental girls performed significantly better on the SAT than the control girls; within the low I.Q. group, the experimental boys performed significantly better than the control boys. Also, within the experimental groups, there were no significant differences between the performance of girls and boys. Therefore, the groups which seemed to benefit most from computer-assisted instruction were boys with a low-measured I.Q. and girls with an average-measured I.Q.

Analysis of Problems. The data obtained from the 1966-67 Brentwood Mathematics Projects were analyzed by using a regression model. The curriculum was divided into six separate categories, and each category was analyzed as a unit. These categories corresponded to arithmetical concepts of sets, geometry, counting, addition, and subtraction. Owing to nonhomogeneity of problem types, the set problems were subdivided into two parts; sets A corresponding to problems in the first half of the curriculum, and sets B corresponding to problems in the second half of the curriculum. For a problem to be included in the analysis, at least 36 students had to attempt it. For latency analysis, it was also required that there be no audio message prior to first response. All

TABLE 17

Testing Results for First-grade Mathematics Curriculum
1966-67

Group	I.Q. (Fall)		SAT (Spring)	
	Experimental	Control	Experimental	Control
Total	91.4	92.9	1.53	1.46
Average I.Q.	99.3	100.3	1.72	1.67
Low I.Q.	82.8	81.9	1.32	1.15

problems that met any of the following three criteria were not included in the analysis. First, in certain lessons the range of difficulty (as measured by proportion correct) was not sufficiently large to make a regression analysis meaningful. Second, because of machine error, there were several lessons for which response data were not reported. Finally, there were 33 lessons that contained problems which dealt with miscellaneous, heterogeneous topics and were, therefore, not amenable to a structural analysis.

The two dependent variables considered were proportion correct and success latency. A set of independent variables was defined for each category and reflected the structural characteristics of the problems studied. In all cases where the definition of a variable did not apply, the value of that variable was zero. The independent variables were:

Sets:

X_{s1} - number of distinguishable symbols on the CRT;

X_{s2} - number of times the order of members of the stimulus set had to be permuted, two at a time, to have the same order as members of the correct choice set;

X_{s3} - one if there exists at least one incorrect choice set with the same cardinality as the correct choice set;

X_{s4} - one if the correct choice is the second or third alternative;

X_{s5} - number of response alternatives;

X_{s6} - one if the empty set occurs in the problem;

X_{s7} - two if the empty set occurs in the problem and is the correct choice and is part of the stimulus; one if the empty set occurs in the problem and the empty set is the correct choice and is not part of the stimulus;

X_{s8} - number of times a member of the correct choice set occurs as a member of the incorrect choice sets;

X_{s9} - one if a blank occurs to the right of a union sign and to the left of the equal sign;

X_{s10} - one if the choices consist of unions of sets.

Geometry:

X_{g1} - if the problem involves the identification of squares or rectangles, X_{g1} is the magnitude of the following sum: two if an incorrect choice has four equal sides, or one if any incorrect choice has four sides, plus three if an incorrect choice has four right angles, or two if an incorrect choice has two right angles, or one if an incorrect choice has one right angle, plus one if an incorrect choice is oriented such that it is supported on its base;

X_{g2} - if the problem involves the identification of triangles, one if there is an incorrect choice with the shape of a triangle;

X_{g3} - one if the correct choice is oriented such that it is supported by one of its sides;

X_{g4} - one if a problem has three choices;

X_{g5} - one if the first choice is the correct choice;

X_{g6} - one if the second choice is the correct choice;

X_{g7} - one if the third choice is the correct choice;

X_{g8} - one if there is an incorrect choice with a non-zero value of X_{g1} or X_{g2} immediately before or after the correct choice;

X_{g9} - one if the problem contains a different number of choices than the immediately preceding problem.

Counting:

X_{c1} - number of distinguishable symbols on the CRT excluding digits and/or names of digits;

X_{c2} - the correct response;

X_{c3} - the value of the smallest incorrect response alternative divided by the difference in value between the smallest incorrect response alternative and the correct response;

X_{c4} - the number of digits displayed;

X_{c5} - one if the problem required a "yes" or "no" response;

X_{c6} - one for each problem in the lesson which first presented N-notation;

X_{c7} - one if the problem required a typed response;

X_{c8} - one for each problem in the first lesson to require counting objects on the scope and choosing a word response or the first lesson to require counting the number of sides of a polygon and choosing a digit response;

X_{c9} - one if the problem was classified as an explanation problem.

Addition:

X_{+1} - number of symbols on the CRT;

X_{+2} - the largest addend;

X_{+3} - the smallest addend;

X_{+4} - the sum;

X_{+5} - the value of the smallest incorrect response alternative divided by the difference in value between the smallest incorrect response alternative and the correct choice;

X_{+6} - two if the blank is to the left of the equal sign and to the left of the plus sign, or one if the blank is to the left of the equal sign and to the right of the plus sign;

X_{+7} - one if the problem required a typed response.

Subtraction:

X_{-1} - the dimuend;

X_{-2} - the subtrahend;

X_{-3} - the difference;

X_{-4} - one if the counting marks were displayed but the number equal to the subtrahend was not crossed out or no counting marks were displayed;

X_{-5} - one if no counting marks were displayed;

X_{-6} - the magnitude of the inverse of the number of times a specific problem had been given up to that point;

X_{-7} - one if a problem had a vertical format.

Tables 18 and 19 summarize the results of the regression analyses.

Insert Tables 18 and 19 about here

The multiple-correlation coefficients show that the fit for success latency was better than the fit for proportion correct. In each of the categories, some of the variables tried were found to contribute significantly to the prediction of the dependent variable, others did not. Significance was determined by means of a t-test on the regression coefficients. It was found the variables that were significant in predicting proportion correct were not necessarily the same ones which were significant in predicting success latency.

This analysis was a first attempt to isolate some of the structural variables which accounted for the difficulty and the latency to success of first-grade mathematics problems, not taking into account the audio messages given with these items. Also, no attempt was made to systematically analyze the types of errors made on the items. Several important factors were found which definitely affected group performance on the items, although certainly not all such factors were discovered. There were indications that suggested the context in which the items were presented was also a significant factor. Finally, areas were found in which our understanding of the structural factors involved was particularly weak, notably, in geometry.

TABLE 18

Regression Coefficients for Brentwood Group Probability Analysis

Concept	Number of problems	Constant	$X_{.1}$	$X_{.2}$	$X_{.3}$	$X_{.4}$	$X_{.5}$	$X_{.6}$	$X_{.7}$	$X_{.8}$	$X_{.9}$	$X_{.10}$	R	R^2
Sets A	94	-3.01	.01*	.13*	.05*	.18*		.16*	.62	.33			.61	.37
Sets B	65	-2.17	.05	.10*		-.19	.04*					-.99	.65	.42
Geometry	48	-5.05	.37	1.04	.05*	.33*	.64*	.91*	.41*	.99*	1.81		.68	.46
Counting	270	-3.02	.11	.04	.01*	.10	.04*	.64*	.32*	.86	.01*		.50	.25
Addition	161	-1.18	-.01*	.11*	.16*	-.06*	.22*	.84	-.63				.51	.26
Subtraction	125	-1.66	-.30*	.26*	.27*	-.58	1.62*	-.97	-.19				.72	.52

*t score for regression coefficient < 2.00

TABLE 19

Regression Coefficients for Brentwood Group Latency Analysis

Concept	Number of problems	Constant	$X_{.1}$	$X_{.2}$	$X_{.3}$	$X_{.4}$	$X_{.5}$	$X_{.6}$	$X_{.7}$	$X_{.8}$	$X_{.9}$	R	R^2
Sets A	44	1.48	.15	.48	.50*					.44		.87	.75
Sets B	40	3.31	.17	.28*	-.61*		.43	-.49*		-.01*		.76	.58
Geometry	24	1.21	.17*	.75*	-.11*	.22*	1.00*				1.74	.67	.45
Counting	110	3.16	.38	.15	.17*	.21		-.57				.81	.65
Addition	99	5.62	.07	.11*	.07*	.43	.10*	1.18	-.99			.70	.48
Subtraction	64	5.28	-.63*	.93	.94	-1.51	3.26	-2.58	-.80*			.82	.68

*t score for regression coefficient < 2.00

Individual models. The analysis of data for individual students in the first-grade mathematics program at Brentwood was completed. The purpose of the analysis was to determine whether certain factors could predict a student's performance on a given set of lessons. Unlike the factors based on problem structure used in the "structural analysis," the factors used in this analysis were measures of prior performance of the individual. Two measures of performance were involved: the proportion of problems which the student answered correctly on the first response, and the student's average latency to the first response on correct problems.

Standard regression models were used to obtain the predictions. Two theories were involved in choosing the specific models. One theory was that the best indicator of a student's future performance is his most recent past performance. This line of reasoning led to the "temporal" models in which the prediction of an individual's performance in a given block of lessons was based on his performance in the immediately preceding blocks of lessons. The other theory was that performance depends on the degree of understanding of the information (terms, symbols, concepts, etc.) necessary to complete the new task. This idea led to the "conceptual" models in which the prediction of an individual's performance on a given set of lessons was based on his performance on previous lessons which exemplified the same concept.

Since the difference in performance for a given individual at two points in the curriculum is a function of both the "normal" variability of the individual and the particular curriculum points chosen, the parameters for the various models were estimated in two ways. The first method, estimation of group parameters, accounted for differences in performance as a function of the curriculum points examined. In this case, one set of parameters was estimated for each set of lessons with the estimation based on the performance of all students on the preceding set of lessons appropriate to the model under consideration. Thus to predict an individual's performance, a different set of parameters was used for each block of lessons; for a given block, the same set of parameters was used for all students.

The second method, estimation of individual parameters, accounted for changes in performance specific to an individual. In this case, one set of parameters was estimated for each student based on his performance on all lessons. Thus to predict an individual's performance, a set of parameters was used which was unique to that student but was the same for all blocks of lessons; for a given block, a different set of parameters was used for each student. The individual estimation technique was modified for some models to include, to some extent, differences in curriculum. Individual parameters for these models were estimated more than once, each based on a different segment of the curriculum (e.g., each set of four lessons). Thus, the set of parameters used to predict an individual's performance was unique to the individual and to the segment of the curriculum under consideration.

Comparisons of the various models were based on a total χ^2 value when proportion correct was the dependent variable and on the S^2 value when latency was the dependent variable (Suppes, Hyman, and Jerman, 1967). For proportion correct, the conceptual models predicted individual performance better than the temporal models with both the group and the individual parameter estimation techniques. Thus, a student's performance on a given topic is more dependent upon his past performance on that topic than upon his more recent performance on a different topic. For latency data, there were no differences between the temporal and conceptual models.

Again, considering data in terms of proportion correct for both the temporal and conceptual models, group parameters gave better predictions than the individual parameters. For the temporal models, the modified individual estimation technique yielded predictions which were better than the individual parameters based on all the student data, but were not as accurate as the group parameter predictions. For the latency data, all models based on group parameters were better than the models estimated by individual parameters.

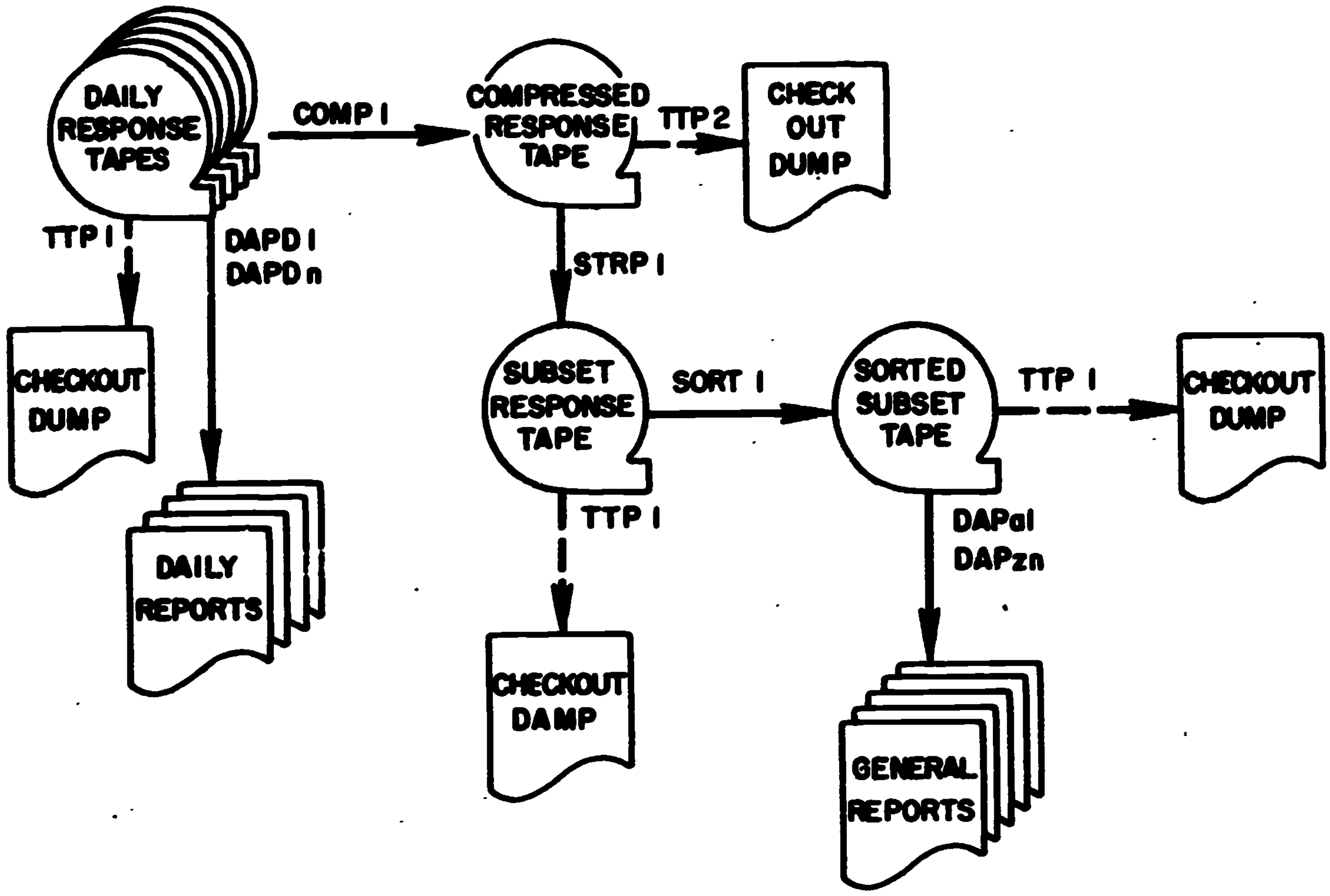
4.4. Data Analysis in Reading

As each student response was input into the system, it was recorded in a concise form that identified the student, the particular problem he was working on, the response made, and the response time. Thus, a complete history was available for each student that was used in making real-time decisions about the instructional sequence, and for later evaluations and analyses. The complexity of this form of data analysis is indicated by the listing of data analysis programs for reading and mathematics in Appendix 2 .

Analysis of response data (1966-67). Each student response was first stored in an area of core memory called a response buffer. When the limit of the storage capacity of the response buffer was reached, the contents of the buffer were read out on a response tape. The steps in the preparation of the response tape for storage and for serious analysis of the student's response data are illustrated in Figure 16. A compressed response tape was generated from the data response tapes by means of a compressor routine which removed the inter-record gaps on the daily response tape. It also was used to compress two or more previously compressed response tapes. It was the compressed response tape that was held in permanent storage.

Insert Figure 16 about here

All items in the student response record were not of immediate interest as far as data analysis was concerned; therefore, items needed for immediate analysis were stripped to form a subset response tape. In the case of the reading program the items stripped were the student number,



COMP1: COMPressor routine number 1.

DAPxn: Data Analysis Program x number n.

SORT1: SORT routine number 1.

STRP1: STRIP routine number 1.

TTP1: Tape To Printer routine number 1.

TTP2: Tape To Printer routine number 2.

Fig. 16. Reading Project Data Analysis Programs

course name, time of day, date, response identifier, the match identifier, and the latency record. The strip routine number 1 also was used to select certain records of interest from the compressed response tape.

A generalized sort/merge program was applied to the subset response tape which handled up to 10 key words in any order within a record and which preserved chronological order in cases of two or more similar entries. By means of the generalized sort/merge routine, a sorted subset tape was generated where the records were recorded first according to student number and second according to problem number (response identifier). A tape-to-printer routine was associated with each tape from the daily response tapes to the sorted subset tape. This routine allowed for listing of the particular tape which then could be examined for completeness and accuracy. It was the sorted subset tapes which were used as input for data analysis programs. The first data analysis program to be discussed here is in reality a data description program at the level of the problem type.

The complexity of the branching routines within a problem type and the variation of the branching logic between problem types made possible an indeterminate number of responses to a given problem by a given student. These responses were then categorized and are illustrated in Figure 17.

Insert Figure 17 about here

The initial response to a problem fell into cell 1. If the response was incorrect, the student was required to respond again to the same problem. Until a correct response was made, subsequent responses fell into cell 2. If the problem type used an optimization routine, then the list of problems was repeated, deleting those problems which received an initial correct response. On each optimization run, there was a first time for a student to respond to each problem. Those first responses fell in cell 3. However, as in cell 1, if that first response was in error, subsequent responses called for on that problem fell in cell 4. There were many cases in the curriculum where a student branched out of a problem type into some appropriate remedial material and then returned to the original problem type. The initial response to a problem in a subsequent entry to a problem type fell in cell 5 and corrections in cell 6. The initial responses of optimization ran on subsequent entries fell in cell 7, and subsequent correction responses fell in cell 8.

This method of classification of responses uniquely defined each response by cell number. Given a sorted subset tape, as specified above, a general algorithm was developed to assign a cell number to each response. The general algorithm was as follows: For a given student and a given problem number, the first response encountered was assigned to cell 1. The second to n^{th} responses were assigned to cell 2 where n

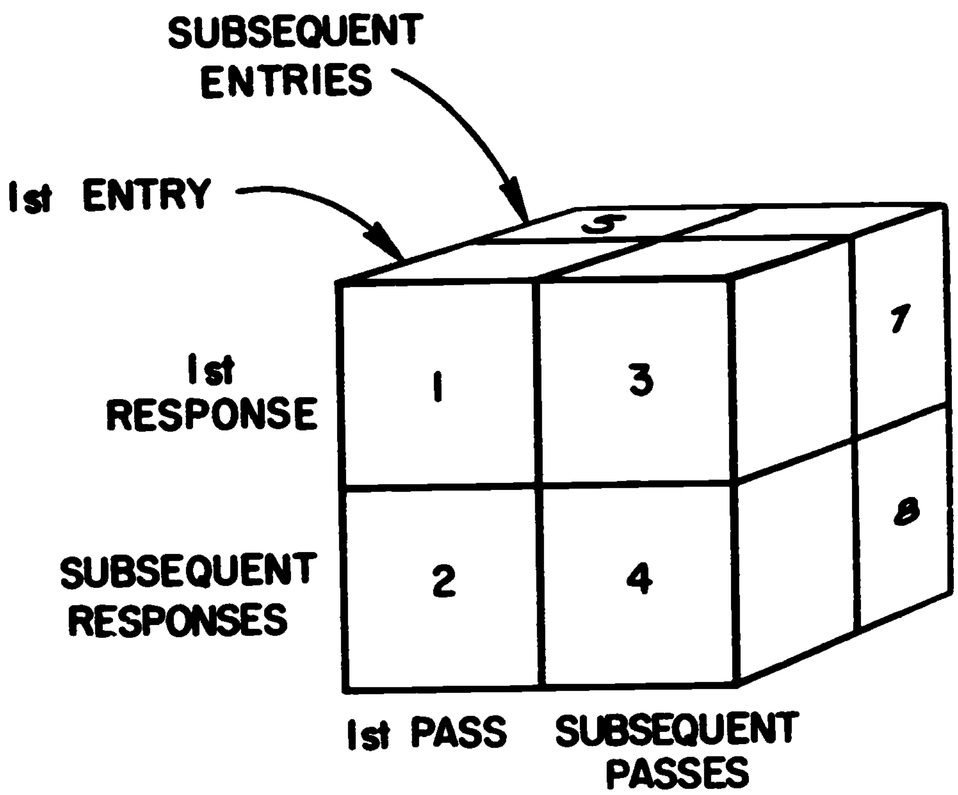


Fig. 17. Response Categorization at the Problem-Type Level, Reading Project

equaled the first CA match identifier. The n+1 response was then assigned to cell 3. The following responses with WA match identifiers, if any, and the next CA match identifier were assigned to cell 4. The next response to the given problem number, if any, was assigned to cell 5. The remaining instructions were essentially a repetition of the first portion of the algorithm. It must be emphasized, however, that this was a general algorithm to which several variations were added to account for the unique branching logic of many of the problem types.

In addition to the above-described cell identification, each response was tagged with a restart run number. If a student signed off for any reason (e.g., end of the period, machine failure) while still at some point within a problem block, he could only start again at the previous restart point. This situation implies that the probability was high that at the beginning of a day a student would be repeating some indeterminate number of problems from the day before. Those responses which resulted from repeated exposure to problems because of restart runs were treated in data analysis in a manner different from those responses given to the original exposure of the problems. The association of problems to restart runs was done during the sort routine between the subset response tape and the sorted subset tape.

Preliminary 1966-67 data were run for (a) analyses of running averages kept on four curriculum blocks; (b) effects of word-usage frequency on the probability of correct responses in the matrix criterion test; and (c) analyses of learning in the matrix block.

Analyses of running averages. The running averages were derived from the proportion of correct answers to the total number of responses requested in the main-line lesson blocks (letter learning, word-list learning, matrix comprehension). The proportions for each lesson were combined with the past lesson data by weighting the past to present results on a four-to-one ratio.

The running averages for four lessons were selected, and intercorrelations between these running averages were computed. The results are shown in Table 20. The lessons selected were Level I, Lessons 5 and

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Insert Table 20 about here

8, and Level II, Lessons 1 and 7. It should be noted that some of the slower students did not progress beyond Lesson I-8, so the number and characteristics of the students differed between Lesson I-5 and Lesson II-7.

Since the correlation coefficient was considered as a measure of how well responses to one variable predicted responses to another variable, it was interesting to observe how well the responses in a specific learning block predicted how the student responded in other

TABLE 20

Intercorrelations Between Running Averages on Four Blocks of the Brentwood Reading Curriculum

Lesson	I-5				I-8				II-1				II-7			
Block	L	W	M	C	L	W	M	C	L	W	M	C	L	W	M	C
I-5 Letter		.48	.37	.33	.95	.42	.47	.45	.89	.34	.53	.40	.69	.34	.29	.37
I-5 Word			.20	.34	.47	.84	.40	.52	.45	.66	.49	.41	.42	.58	.56	.53
I-5 Matrix				.14	.31	.24	.81	.16	.45	.44	.68	.28	.48	.47	.43	.37
I-5 Compre.					.31	.34	.32	.76	.42	.34	.40	.88	.33	.45	.51	.63
I-8 Letter						.43	.36	.38	.95	.37	.39	.33	.73	.31	.07	.15
I-8 Word							.45	.61	.42	.80	.44	.43	.45	.70	.55	.47
I-8 Matrix								.48	.52	.60	.81	.46	.46	.70	.62	.59
I-8 Compre.									.44	.55	.55	.86	.43	.63	.64	.71
II-1 Letter										.36	.40	.44	.80	.30	.10	.28
II-1 Word											.57	.35	.46	.83	.63	.59
II-1 Matrix												.55	.41	.74	.86	.72
II-1 Compre.													.30	.62	.65	.83
II-7 Letter														.43	.37	.28
II-7 Word															.77	.62
II-7 Matrix																.68
II-7 Compre.																

blocks. The circled correlations in Table 20 are estimates of how well the responses to the block represented in the left-hand column predicted responses in the same blocks in other lessons. For example, the letter block of Lesson I-5 predicted very accurately the responses in the letter block of Lesson I-8 with a correlation coefficient of .95. However, as the lessons progressed, the correlation decreased. This decrease would suggest that the most recent information was the most valuable predictor. This same pattern seemed to be maintained in all of the blocks, with the exception of the comprehension block in Lesson I-5, which predicted the results of Lesson II-1 better than it did those of Lesson I-8.

The correlations within the triangles were the predictions from responses of each block within a lesson to responses from all other blocks within the lesson. As an example, the running average for the word block in Lesson I-5 did not predict very accurately the running average of the matrix block (correlation of .20). In Lesson I-8 however, this correlation increased to .45 and continued to increase as the lessons progressed. An explanation of this increase is being investigated.

The effect of word-usage frequency on the probability of correct responses in the matrix criterion test. A second preliminary analysis was based on data from the first-response data tape, which contained initial student responses to problems when first encountered. The data was sorted by lesson and, within each lesson, by student. The students were divided into the following groups: (a) High I.Q. (median = 107, range = 23), (b) Middle I.Q. (median = 94, range = 11), (c) Low I.Q. (median = 79, range = 32).

The words for the first eight lessons were divided into the following groups: (a) High frequency (Lorge-Thorndike frequency > 200); (b) medium frequency (Lorge-Thorndike frequency < 200 and > 10); (c) low frequency (Lorge-Thorndike frequency < 10 and ≥ 0); (d) letter strings (consonant-vowel-consonant letter strings).

The proportion of correct responses each student made for each group of words was used as the measure in the analysis. Figure 18 indicates the mean proportion of correct responses on the matrix criterion test for the four-word groups and for each I.Q. group.

Insert Figure 18 about here

A two-way analysis of variance of these data showed there was a significant difference between both the I.Q. groups and the responses to the different word groups. There was no significant interaction, however, between the I.Q. groups and word groups, which suggested that the patterns of response to the criterion tests were the same for each I.Q. group.

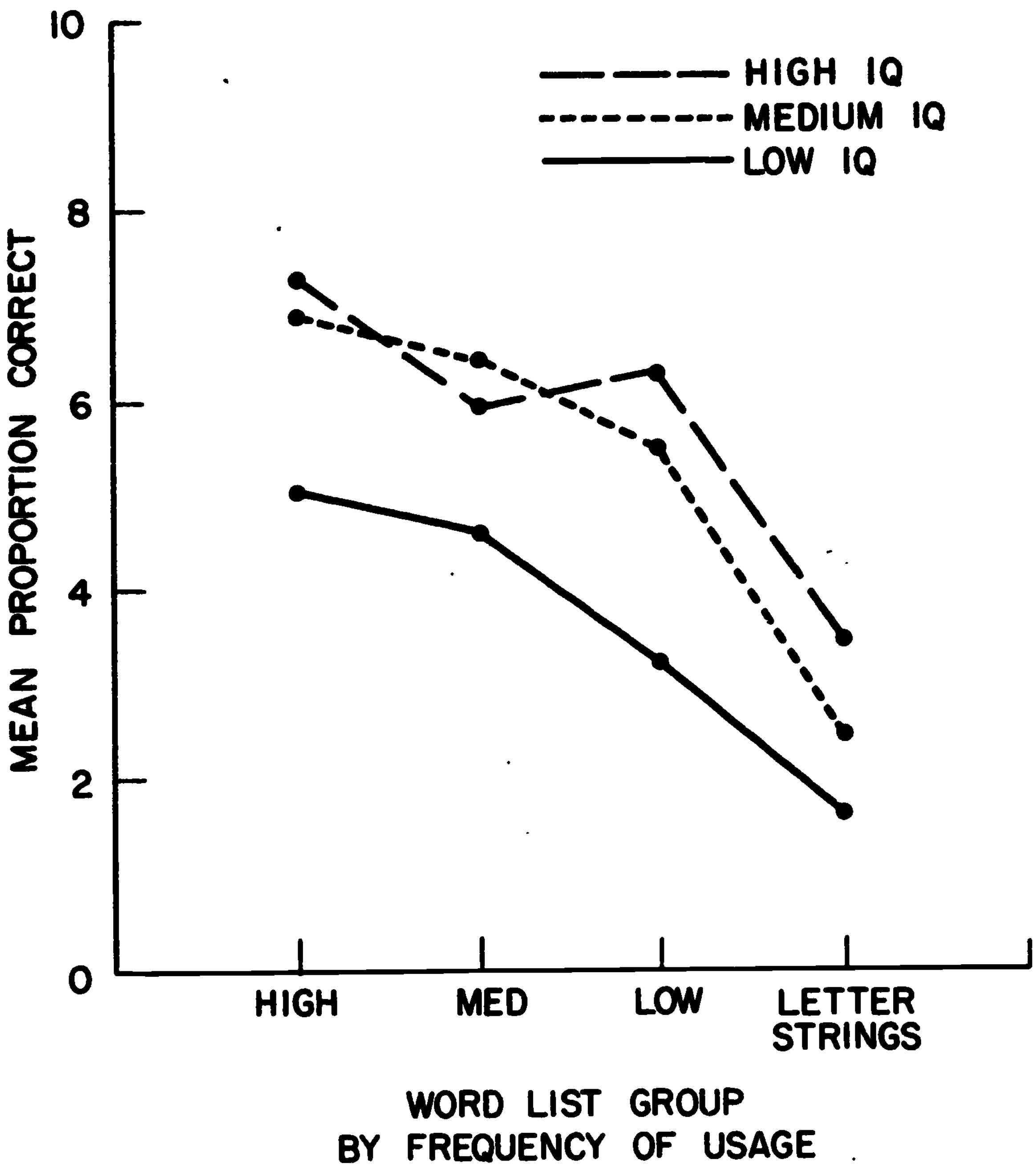

Fig. 18. Mean Proportion Correct of Word List for Three I.Q. Groups, Reading Curriculum

The analysis, which involved all the new words presented in the first eight lessons, indicated that there was a significant difference in the proportion of correct responses on the matrix criterion test for the students grouped by I.Q., and for different word-frequency groups among all the students.

It was hypothesized that ignorance of the matrix concept was responsible for the significant drop in correct responses for the letter strings (nonsense items of zero frequency). In order to test the above hypothesis, a second analysis was made using the new words presented in Lessons I-9 through I-13. Assuming that the children had correctly learned the matrix concept by these later lessons, one would expect that frequency of word usage would no longer be a significant predictor of their performance.

Figure 19 is a graph of the mean responses for the words in the first eight lessons and the words in Lessons I-9 through I-13. Table 21

Insert Figure 19 about here

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shows the mean and standard deviation for lists of each frequency. The

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Insert Table 21 about here

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t-tests between word lists showed that the high, low and letter-string lists were not significantly different at $p = .01$. The middle-frequency word group, however, was significantly higher than both the letter-string and the low-frequency word groups as shown in Table 21.

The shift of the highest proportion of correct answers from the high-frequency list to the middle-frequency list suggested, along with the lack of significant differences between the other three word lists, that word frequency was not a significant factor in predicting the proportion of correct responses for students on the matrix criterion test.

The analysis of learning in the matrix block. The third preliminary analysis concerned learning in the matrix block. Matrix construction was a key learning activity present in each lesson. Certain regular, highly productive rhyming and alliterative word patterns were taught. Rhyming patterns were presented in the columns of a sounding matrix.

	an
r	ran
f	fan
c	can

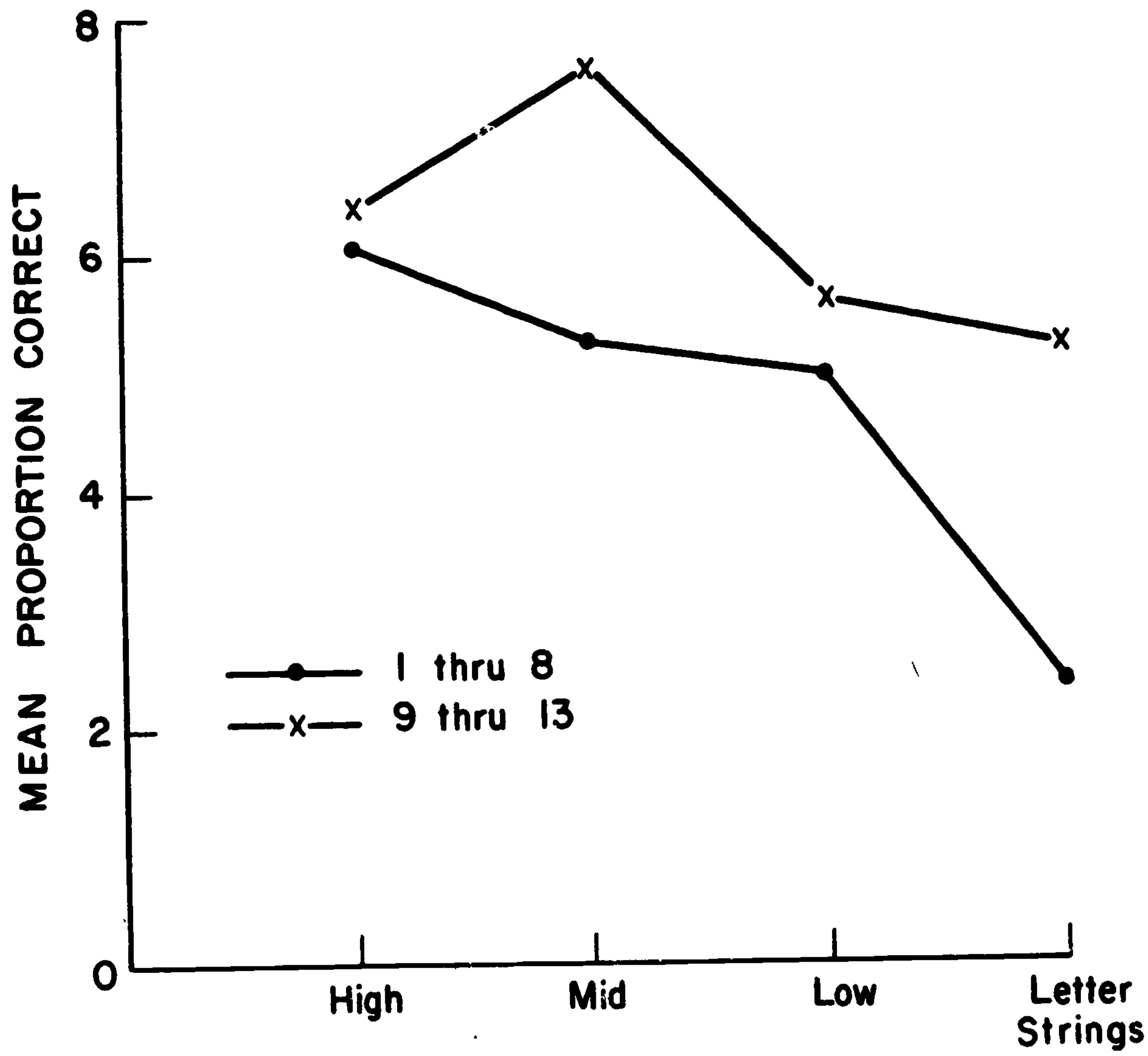

Fig. 19. Word-List Group by Frequency of Usage, Reading Curriculum

TABLE 21

Mean and Standard Deviation for Reading Curriculum Lists for Each Frequency

	Mean	Standard Deviation
<u>List I</u>		
High	0.63	0.30
Mid	0.55	0.30
Low	0.52	0.31
L.S.	0.26	0.29
<u>List II</u>		
High	0.64	0.23
Mid	0.72	0.24
Low	0.58	0.28
L.S.	0.54	0.28

Alliteration patterns were presented in the rows of the matrix.

	an	at	ag
r	ran	rat	rag

The matrix was constructed one cell at a time. In the course of an errorless trial, the student heard the word pronounced three times and was asked to identify and pronounce it twice. In the initial presentation, the multiple-choice items were designed to identify three possible classes of error: (a) a correctly identified initial unit, but an incorrect final unit; (b) a correctly identified final unit, but an incorrect initial unit; or (c) incorrectly identified initial and final units. There was a special remedial treatment appropriate for each class of error. After all words in the matrix were presented, and remedial and practice exposures were completed, a subset of the items was presented in a criterion test.

The first-exposure data obtained from this matrix block is summarized as follows. Only the words used in the criterion test were considered. For these, a student's performance on the initial presentation and on the criterion test was examined, and responses were classified by types of error. The data from all students completing a given lesson were then summarized in a table of joint probabilities, which was used to estimate theoretical parameters that represented a condensed description of the data for the matrix block on the lesson in question. The parameters estimated were: (a) proportion of words known on entry to the block; (b) proportion of words for which the initial unit only was known on entry; (c) proportion of words for which the final unit only was known on entry; (d) proportion of unknown initial units learned before the criterion test; (e) proportion of unknown final units learned before the criterion test; (f) probability of not making a response when a word was not known.

An analysis of performance on the matrix task is still incomplete, but some preliminary results are available. On the initial pass (Part A) the students were correct about 45 per cent of the time; however, when an error did occur, 21 per cent of the time it involved only the final unit, 53 per cent of the time only the initial unit, and 26 per cent of the time both initial and final units. The pattern of performances changed markedly on the first pass through the criterion test. Here the subject was correct about 65 per cent of the time; when an error occurred, 32 per cent of the time it involved only the final unit, 33 per cent of the time only the initial unit, and 35 per cent of the time both units. Thus, performance showed a significant improvement from Part A to the criterion test; equally important, initial errors were more than twice as frequent as final errors in Part A, but were virtually equal on the criterion test.

Weekly report. A report on student progress was generated each week during the school year of 1966-67, primarily as information for the teachers. The report contained the individual student's name, identification of the lesson the student was working on, the number of proctor calls received for that student during the week, and a cumulative weighted index of the student's performance for each of the six major problem blocks (i.e., letter discrimination, word presentation, matrix construction, comprehension, compound words, polysyllabic words). Also included in the report were the cumulative number of sessions the student had on the machine, his number of absences during the week, and the total amount of time off the system that week. The last three categories were computed from the teaching proctor records. The remainder of the report was generated by reading pertinent items from the student records. The performance index for each student in each of the six problem blocks was computed in the following manner. A series of six counters were assigned for the computation of the performance index. As a student proceeded through a problem block, the counter for that block was indexed to indicate the proportion of initial correct responses. When the student completed the block, the contents of that register were used to update the associated performance index in the student record. The standing value for the register was read out and the new value was added. The updating of the register, however, was done by using a weighting formula: $I_n = I_{n-1}\ (.40) + I_n\ (.60)$. The weighting procedure was used to reflect more accurately the student's current performance in relation to his past performance. Computations were made, however, in the integer mode which made the index somewhat conservative.

Although the weekly performance report was prepared primarily for the classroom teacher and the teaching proctors, it provided sufficient data for examining several rather general questions of overall student performance. The weekly student performance record was used in the two following analyses.

Spread on main line. A central core of problems within the lesson material were considered main-line problems in the sense that they were problems for each student to master. A student branched around blocks of main-line problems by successfully passing certain screening tests. On the other hand, a student branched to appropriate remedial material if he had difficulty with these central problems; but in every case he returned to that set of main-line problems for which remedial material was introduced.

Each lesson contained an average of 125 main-line problems. Therefore, the number of lessons completed by a student was used as an index of the number of main-line problems successfully completed. Figure 15 shows the number of main-line problems completed each week by the fastest, slowest and median student. This information was derived by identifying the student who had completed the most lessons on the final student progress report for the week of June 14, and from the same report, identified the median student and the slowest student, considering only those students who had begun the program on November 15, 1966. New students who had moved into the school and the remedial second-grade students were not considered in the derivation of Figure 15. (See page 87.)

The year ended with a difference between the fastest and slowest student of 4,125 problems completed. The inter-quartile range was 1,375 problems, and the median student completed 2,625 main-line problems. There was, however, a rather wide variation in the amount of time spent on the system by the students. In order to take this variation into account, a rate-of-progress score was computed by dividing the number of problems completed at the end of the year by the number of sessions that the student had on the system. The cumulative rate of progress for the highest, lowest, and median student is shown in Figure 20, and is expressed in terms of number of main-line problems completed per hour of instruction. The range in rate of progress was between 35 problems per hour for the slowest student to 170 main-line problems per hour for the fastest student. The inter-quartile range was 45 to 110 with the median at 75 problems per hour.

Insert Figure 20 about here

From both the total number of main-line problems completed during the year and the rate of student progress, it is clear that the CAI reading curriculum has accounted for individual differences on at least one dimension (i.e., the movement of the individual student through the lesson material). As shown in Figures 15 and 20, the differences are not to be confused with a variation in rate of response. The differences in the rate of response between students was very small--approximately four responses per minute. The differences in the total number of main-line problems completed and in the rate of progress were accounted for by the amount of remedial material, the optimization routines, the number of corrections, and the number of accelerations for the different students.

Sex differences. Generally, girls surpass boys in the acquisition of reading skills and in reading performance, particularly in the primary grades (Gates, 1961;[1] Wyatt, 1966[2]). These differences might be attributed, at least in part, to the social organization of the classroom and to the value and reward structures of the predominantly female primary-grade teachers. It has also been argued that because of differences in developmental rates, first-grade girls are more adept in visual memorization than boys of the same age--a capability that would favor girls in the sight-word method of vocabulary acquisition commonly used in the current basal reading series. If these two arguments are viable,

[1] Gates, A. Q. Sex difference in reading ability. The Elementary School Journal, 1961, 61, 431-434.

[2] Wyatt, N. M. Sex differences in reading achievement. Elementary English, 1966, 43, 596-599.

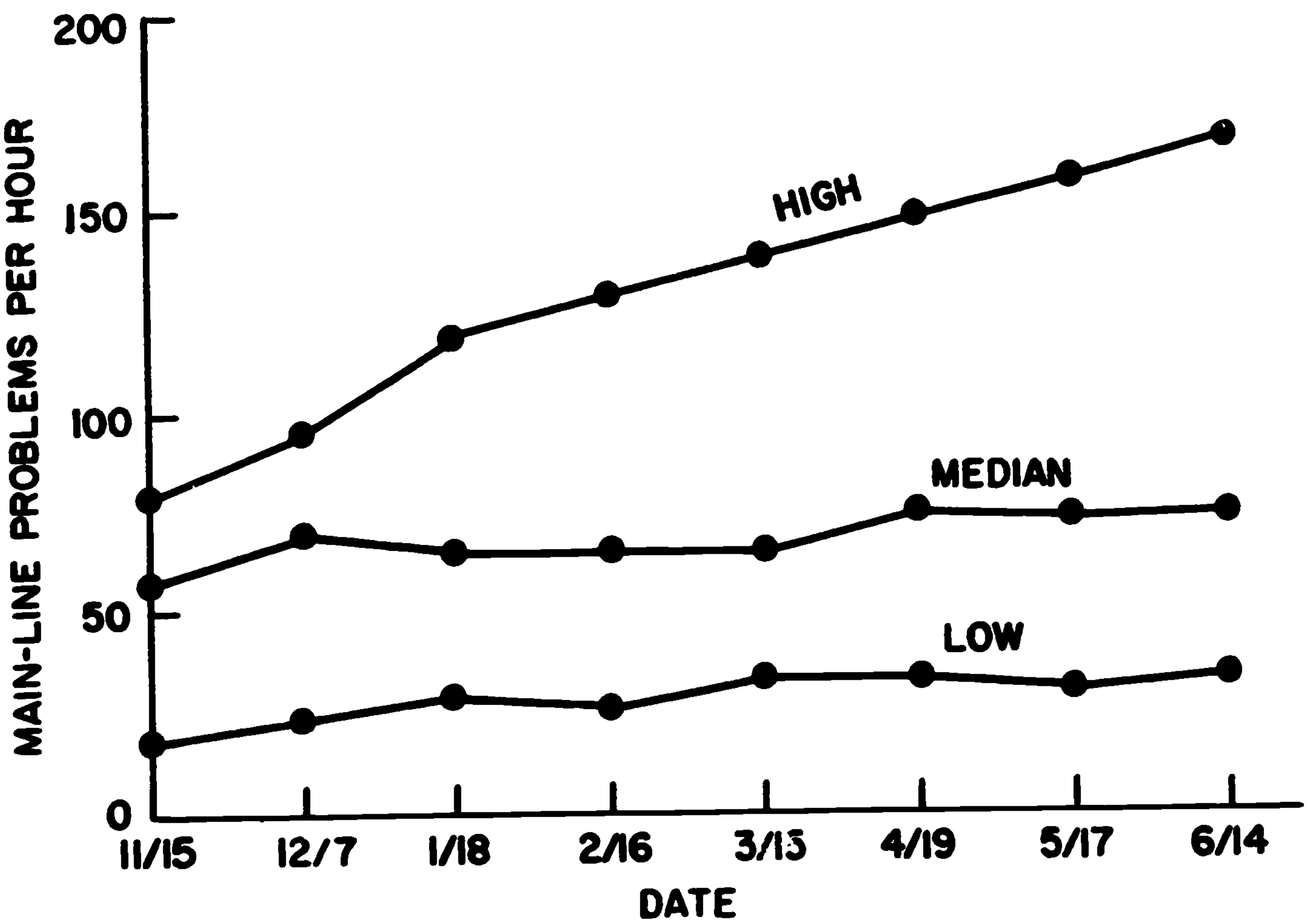

Fig. 20. Cumulative Rate of Progress of Fastest, Median, and Slowest Students in CAI Reading Program

then one would expect that placing students in an asocial environment, such as a CAI tutorial system, and presenting a linguistically oriented curriculum emphasizing analytic skills as opposed to rote memorization of words, would minimize the sex difference in reading performance. In order to test this notion, the rate-of-progress scores taken from the final teachers' reports were rank ordered and tested for significant sex effects using a Mann-Whitney U-Test. The null hypothesis in this and in the following tests was that the scores for the boys and the scores for the girls had the same distribution. The test of sex effects yielded z of .05. Under the null hypothesis, the probability of z being greater than or equal to 0.35 was 0.36. Sex difference then is not an influential variable in the rate of progress in the Stanford CAI reading curriculum.

To test the notion that sex differences still might be an influential factor in accuracy of performance, the final performance index scores for each of the four standard problem blocks reported on the weekly teachers' reports were rank ordered and examined under the Mann-Whitney U-Test. The results were as follows:

Letter identification; $Pr(z \geq 0.33) = 0.37$.
Word list; $Pr(z \geq 1.83) = 0.03$.
Sounding matrix; $Pr(z \geq 1.41) = 0.08$.
Sentence comprehension; $Pr(z \geq 1.37) = 0.09$.

The only significant difference, at the 0.05 level, was found in the word-list scores. The scores in the matrix and comprehension sections, however, were in the expected direction (i.e., girls excelling boys). These results, while by no means definitive, supported the notion that when students were removed from the normal classroom social milieu and placed in the asocial environment of a CAI tutorial system, boys performed as well as girls in overall rate of progress through a reading curriculum. The results also tended to support the idea that in a CAI environment the sex difference was minimized in direct proportion to the emphasis on analysis versus rote memorization in the learning task. The one problem section where the girls achieved significantly higher scores than the boys was the word-list section which was a paired-associate list-learning task.

Achievement tests. Even though the first year's operation of the system was viewed as an extended debugging process, it was felt that a comprehensive end-of-the-year testing program might yield some interesting insights to the potential impact of the program on overall reading achievement. Accordingly, a battery of tests was assembled to measure achievement in each of the major areas of reading behaviors taught at the first-grade level. The behaviors identified and included in the testing program were:

1. Identification of letter and letter-strings.

2. Acquisition of an initial sight vocabulary.

3. Acquisition of word decoding skills:
    a. initial consonants;
    b. initial consonant clusters;
    c. medial short vowels;
    d. final consonants.

4. Acquisition of reading comprehension skills:
    a. word meaning;
    b. syntax or form class for sentence comprehension;
    c. paragraph comprehension:
        (1) main idea;
        (2) recall of facts.

Wherever possible, standardized tests of the reading behavior to be evaluated were chosen. In several cases, the tests only approximated what we were trying to measure or were not pure tests of a single reading behavior. As far as could be determined, none of the available test batteries included tests of all the reading behaviors listed above. It was particularly difficult to find group-administered tests measuring a child's ability to decode words and the child's knowledge of syntax or form class behaviors; therefore, Ruth Hartley of the project staff devised tests of these behaviors.

The tests chosen for this test battery were derived from the following sources: (a) Gates-MacGinitie Reading Test, Primary A, Form 1, 1965 edition; (b) California Reading Test, Lower Primary, Form W, 1957 edition with 1963 norms; (c) Stanford Achievement Test, Reading Sections, Primary 1 Battery, 1964 edition; (d) project developed tests.

The students in the CAI mathematics program provided an ideal control group. Analysis of the individually administered Stanford Binet I.Q. tests at the beginning of the school year indicated that students in the reading program and students in the mathematics program could be considered as two samples from the same population. The mean I.Q. for the reading group was 92.5 (standard deviation 15.6), and the mean I.Q. for the mathematics group was 91.8 (standard deviation 14.6). Any Hawthorne effect induced by the CAI experience was controlled, since the mathematics students had an equal amount of time on the system but for a different subject matter. The mathematics students received a traditional program of reading instruction, relying primarily upon the Ginn and the Alyne and Bacon first-grade readers.

All tests, with the exception of the Stanford Achievement Test, were administered by members of the project staff, assisted by graduate students from the School of Education at Stanford University. Each testing team, a project staff member and a graduate student, administered a given test for all students in order to eliminate tester effects. The Stanford Achievement Test was administered by the individual classroom teachers as part of the testing program of the State of

California. All tests were conducted within the normal classroom setting during the month of May, 1967.

The content and characteristics of the three standardized tests in the battery are well known and need not be reiterated here; however, a brief description of the project-developed tests might be helpful in the interpretation of the results.

Vocabulary test. This test used words and patterns that were presented in the CAI program. Some of the words and all of the word patterns included in this test also appeared in the Ginn and Alyne and Bacon first-grade basic readers. The test contained 20 sets of three words each. The student was directed to circle the word pronounced by the examiner.

Phonetic discrimination. This test checked the child's ability to distinguish between minimal contrasts of monosyllabic words and to connect the auditory sound of a phoneme with its grapheme. The test contained two sections: (a) identity of a pronounced word by the test administrator from a set of three words (e.g., bat, rat, sat); and (b) filling in the missing letter or letters in a word pronounced by the administrator. In both cases, the test dealt with initial consonants, initial consonant clusters, medial short vowels, and final consonants.

Reading comprehension: understanding of syntax or form class behaviors. This test contained 20 sentences in which one word was omitted. The subject was required to choose the correct word from a set of four words that would complete the sentence. The distractors in the multiple-choice set consisted of one word which was the correct form class but was semantically irrelevant, and words from two incorrect form classes. The vocabulary was derived from the first 40 lessons of the CAI program and the Ginn and Alyne and Bacon first-grade readers.

Pronunciation. The pronunciation test was composed of 40 items; 20 real monosyllabic words and 20 pronounceable nonsense monosyllabic units. Each nonsense item was composed as a minimal contrast to a real word item (e.g., man, fam). Five pairs were constructed for each of four categories of minimal contrast: initial consonant, medial vowel, final consonant and initial consonant blend. Each item was typed in lower-case primary type on a 3" x 5" card and presented to the subjects one at a time. The subjects were required to pronounce each item.

Student responses were recorded on magnetic tape for detailed future analysis. The results reported in this paper are those of the all-or-none scoring procedure, i.e., an item was scored as correct only if all phonemes of the item were correctly pronounced and in proper sequence.

Overall results. The results of each of the above tests and their major subsections were examined in a series of three-way analyses of variance (treatment, high/low I.Q., sex). No significant interactions were found in any of the analyses. The expected significant differences on the I.Q. and sex variables were found throughout the tests and were of little interest. The means and standard deviations for each test for both the experimental and control groups are shown in Table 22. It is interesting to note that with the exception of two cases (Stanford Achievement Test, paragraph reading and total score), the direction of differences between the means is in favor of the experimental group.

Insert Table 22 about here

The test battery was divided into two major categories: (a) tests designed to evaluate the goals and linguistic orientation of the CAI program; and (b) tests designed to evaluate outcomes of a quite different approach to initial reading (i.e., the traditional basal reading series approach). Differences between the means of each of the project-developed tests were statistically significant, and in one case, the pronunciation test, the differences were fairly dramatic. Statistical significance was also achieved in three of the eight sub-scales of the standardized tests. Two of those sub-scales, the vocabulary section of the California Achievement Test and the word-study skills section of the Stanford Achievement Test, were composed of a series of tests of sub-skills. It was necessary, therefore, to investigate the possibility that large differences on one or two of the sub-skills might exert an influence powerful enough to produce significance in the sub-scale as a whole. Accordingly, the scores on each test of sub-skills were examined in the same three-way analysis of variance as described above. The results may be seen in Table 23. The significance levels held in all four of the sub-skills for the word-study section of the Stanford Achievement Test and in three of the five tests of sub-skills in the vocabulary section of the California Achievement Test.

Insert Table 23 about here

The impact of CAI instruction on reading performance is shown by tabulated results of reading behaviors measured in the evaluation program in Table 24. Eight of the nine tests of decoding skills resulted in differences significant at the .05 level in favor of the CAI group and in six of those eight tests the significance was at the .01 level or beyond. Three of the tests of comprehension at less than the paragraph level resulted in differences in favor of the CAI group significant at the .05 level. No significant differences were found in the tests of comprehension at the paragraph level.

Insert Table 24 about here

TABLE 22

Means and Standard Deviations: Major Test Sections, Reading Project

	Experiment		Control		Significance level
	Mean	S.D.	Mean	S.D.	
Gates[a]					
Vocabulary	41.1	9.26	39.3	9.01	N.S.
Comprehension	39.5	8.93	38.8	9.12	N.S.
Total	38.5	9.07	37.4	9.02	N.S.
C.A.T.[a]					
Vocabulary	45.9	1.76	38.1	2.02	$p < 0.01$
Comprehension	41.4	2.51	40.6	2.16	N.S.
Total	45.6	0.58	39.6	1.01	$p < 0.01$
S.A.T.[a]					
Word Reading	40.3	4.84	40.0	2.44	N.S.
Para. Reading	36.0	9.73	38.5	4.07	N.S.
Vocabulary	41.7	3.89	40.7	2.05	$p < 0.01$
Word Study	45.9	3.72	44.9	2.50	$p < 0.01$
Total	44.2	5.89	44.6	3.76	N.S.
Project[b]					
Form Class	8.6	5.23	6.4	4.95	$0.01 < p < 0.05$
Vocabulary	17.7	4.16	15.7	4.27	$p < 0.01$
Pronunciation	11.28	10.21	4.94	7.66	$p < 0.01$
Phonetic Discrim.	14.06	20.07	10.63	15.32	$p < 0.01$

[a]Standard scores: M = 50, S.D. = 10

[b]Raw scores

TABLE 23

Means and Standard Deviations: Sub-Scales, Reading Project

Test	Experiment		Control		Significance Level
	Mean	S.D.	Mean	S.D.	
C.A.T.					
Vocabulary:					
Word Form	18.3	5.13	15.0	5.30	$p < 0.01$
Word Recognition	13.4	4.87	11.7	4.50	$0.01 < p < 0.05$
Opposites	6.2	2.96	5.7	2.70	N.S.
Picture Association	8.2	2.92	6.8	2.26	$p < 0.01$
Letter Recognition	21.2	5.17	20.6	6.20	N.S.
S.A.T.					
Word Study:					
Audio Perception					
Beginning Sounds	9.87	2.71	8.00	2.70	$p < 0.01$
Ending Sounds	8.89	2.77	6.78	3.13	$p < 0.01$
Phonics	10.20	2.54	8.89	2.70	$p < 0.01$
Phonograms	7.28	2.88	6.33	2.18	$0.01 < p < 0.05$

TABLE 24

Significance Levels of Tests of Reading Behaviors

Reading Behaviors Measured	Test*	Significance Level .01	.05	N.S.
A. <u>Decoding</u>				
1. Letter and Letter String Identification	1			x
	2	x		
2. Initial Sight Vocabulary	3		x	
	4p	x		
3. Word Decoding Skills	5	x		
	6	x		
	7		x	
	8	x		
	9p	x		
	10p	x		
B. <u>Comprehension</u>				
1. Word Meaning from Picture Cues	11			x
	12			x
	13	x		
2. Word Meaning - Vocabulary	14	x		
	15			x
3. Understanding of Syntax and Form Class	16p		x	
4. Sentence, Paragraph and Story Comprehension	17			x
	18			x
	19			x

TABLE 24 (cont.)

	*Test	Number of Items
1.	C.A.T., Letter Recognition Test	24
2.	C.A.T., Reading Vocabulary-Word Form Test I, Section A	25
3.	C.A.T., Reading Vocabulary-Word Recognition, Test I, Section B	20
4.	Hartley Vocabulary Test	20
5.	S.A.T., Word Study Skills Auditory Perception of Beginning Sounds	14
6.	S.A.T., Word Study Skills Auditory Perception of Ending Sounds	14
7.	S.A.T., Word Study Skills Phonics - Recognition of Word from Spoken Cues	14
8.	S.A.T., Word Study Skills Phonograms - Rhyming Words	14
9.	Hartley, Phonetic Discrimination	40
10.	Hartley, Pronunciation Test	20
11.	Gates, Vocabulary Test - Picture Association	48
12.	S.A.T., Word Reading - Picture Association	35
13.	C.A.T., Vocabulary - Picture Association Test I, Section D	15
14.	S.A.T., Vocabulary	39
15.	C.A.T., Vocabulary - Meaning of Opposites, Test I, Section C	15
16.	Hartley: Form Class	20
17.	Gates, Comprehension Test	34
18.	C.A.T., Comprehension - Test 2	15
19.	S.A.T., Paragraph Meaning	38

These results were most encouraging for the potential impact of CAI on initial reading since even the fastest student in the first year's program progressed only a small fraction of the way through the first year's curriculum, which was designed with the expectation that the able student would complete approximately 180 lessons in the first year. As seen in Figure 21, the top student in this year's program completed only approximately 22 per cent of the expected total number of lessons. The average student in this year's group completed only 11 per cent of the total first year's program.

Insert Figure 21 about here

A comparison of Table 4 and Figure 21 will verify that no student in this year's run was exposed to more than five basic patterns: ac; cac; ccac; ic; and cic (where c stood for any consonant and each vowel was specified). A significant increase in performance in 9 out of 10 tests of decoding skills was achieved by this minimal exposure. Since six of the nine tests were commercial standardized tests whose vocabulary and word patterns were not based on the Stanford CAI program, it was assumed that some transfer of learning took place. Transfer of learning was also observed by classroom teachers; particularly by the teacher of the low maturity group who reported that a noticeable percentage of these students discovered word patterns in their classroom reading and generalized those word patterns in the attack of new words.

The most consistent results were found in the decoding skills, the area of initial reading handled in greatest detail by the Stanford CAI program. On the other hand, results in the comprehension tests were mixed, with no significant differences being found in tests of paragraph comprehension. Even the fastest student in this year's program failed to reach the level in the lesson material introducing exercises on the comprehension of connected discourse. As stated earlier in this paper, the comprehension exercises in the Stanford CAI curriculum served more in the nature of data gathering devices than as a well-defined and complex teaching effort.

Analysis of response data (1967-68). From September 1967 to March 1968, students in the Experienced Teacher Fellowship Program on two separate occasions observed and recorded subject behavior and attitudes. Table 25 indicates the results of children's behavior at the CAI terminals during the first set of observations.

Insert Table 25 about here

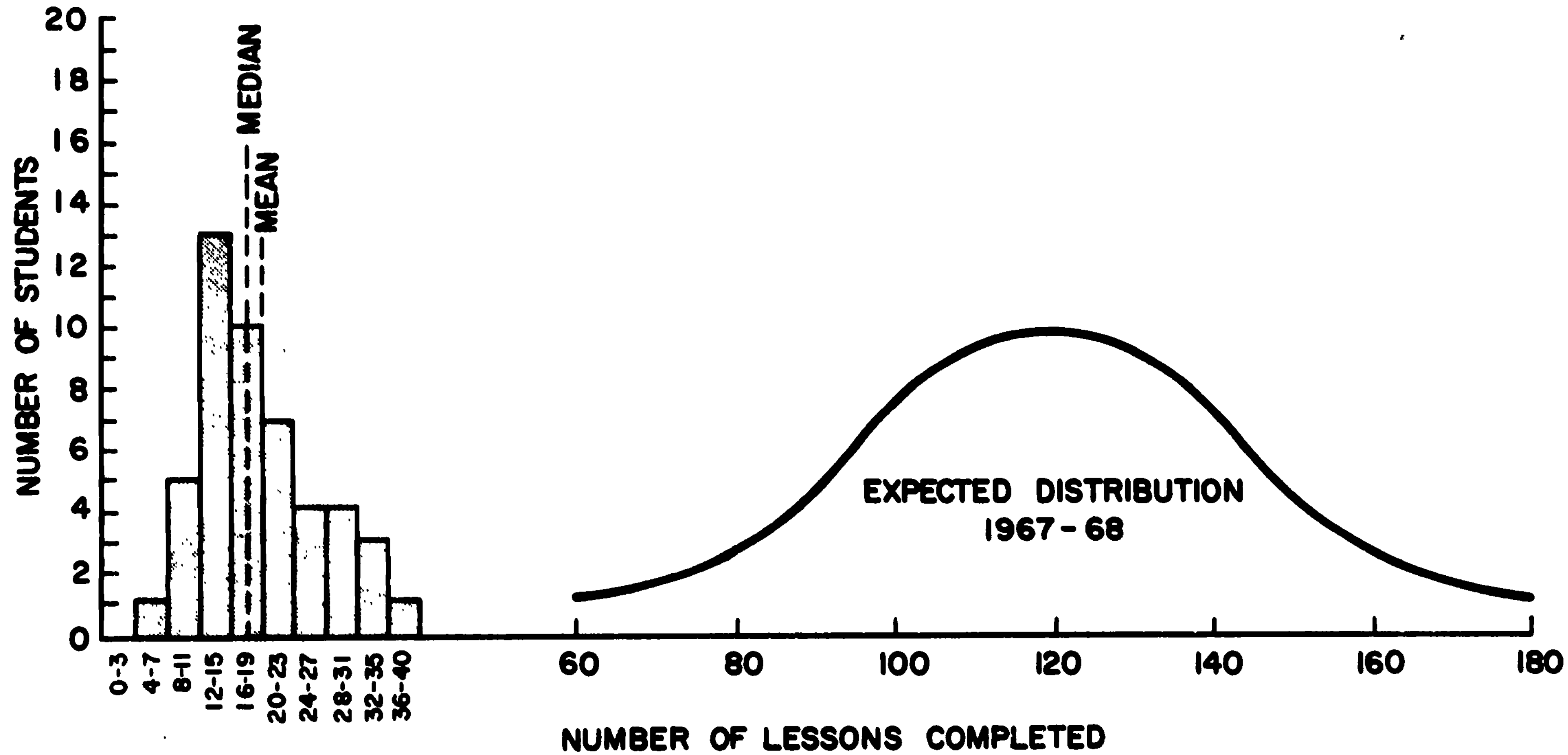

Fig. 21. Distribution of Students over Reading Lessons (1966-67)

TABLE 25

Results of Children's Behavior Working at CAI Terminals,
Reading Project

Observed behavior	Variable number	Mean	S.D.	S.E. of mean	Sample	Maximum	Minimum	Range
Looking at scope or projector	1	17.1644	3.0185	0.3533	73	20.0000	8.0000	12.0000
Twisting in chair	2	3.8082	2.9705	0.3477	73	14.0000	0.0	14.0000
Watching others	3	1.0274	1.6581	0.1941	73	9.0000	0.0	9.0000
Looking over or under partitions	4	0.0548	0.4682	0.0548	73	4.0000	0.0	4.0000
Playing with keyboard	5	0.0822	0.4331	0.0507	73	3.0000	0.0	3.0000
Playing with light pen	6	0.2466	0.6827	0.0799	73	4.0000	0.0	4.0000
Playing with projector or scope	7	0.0959	0.4461	0.0522	73	3.0000	0.0	3.0000
Looking or making faces in mirrors	8	0.0274	0.1644	0.0192	73	1.0000	0.0	1.0000

The eight basic behavior categories outlined in this table were looked for in each child for 5 minutes at the beginning, in the middle, and at the end of a period. During each 5-minute period, the observer checked the type of behavior displayed every 15 seconds. Thus, for the entire sample of 73 students, any specific behavior was observed a maximum of 20 times during the 5-minute period for a given student. Variable 1 (looking at scope or projector) represented a desirable behavior while Variables 2 to 8 were relatively undesirable. The table indicates that Variable 1 was predominant with a mean of 17.2 out of a possible 20 for the entire sample. The Maximum and Minimum columns indicate that although at least one student exhibited the desirable behavior only eight times during the observation period, several children exhibited the desirable behavior a near maximum number of times (i.e., 20 times). The means for Variables 2 to 8 indicate a minimal amount of undesirable behavior, which was often caused when the system functioned at a slower than normal rate.

Weekly report. A weekly report provided information about student progress to the teachers and proctors and also served to identify learning difficulties experienced by the students in sufficient detail so that corrective measures were devised and implemented. The information was derived from recorded responses by the students that included the date; relative response time; student identification number; identification of the specific problem; actual response coordinates; nature of the response (i.e., correct, wrong, overtime, unidentifiable); latency in making the response; and positions of various switches and contents of various counters used in curriculum sequencing and branching procedures.

The student's rate of progress through the curriculum was dependent on four different branching sequences: (a) repetition within a specific problem type using optimization procedures; (b) repetition of problem types to obtain more practice to pass successive problem types; (c) completion of additional remedial material to compensate for apparent deficiencies in student experience; and (d) the branching to off-line tutorial help given by a teacher. A proctor branched the student to off-line remedial help when the CAI system indicated that the student had worked on a single block of problems for more than two days. The off-line remedial help lasted a minimum of one full session and continued on sequential days at the discretion of the teacher.

The sequence of problem types to which the student was exposed each day within any one lesson, and within a week, recorded the path a student followed through the curriculum. Table 26 shows a typical sequence of problem types.

Insert Table 26 about here

TABLE 26

Student's Sequence Through Lessons, Brentwood Reading

Weekly Report
Student Number - Name
J104 John Cannon

Date	Lesson	Student's sequence through lesson
3-18-68	AI	WA WP WC WN //*WN WP WC GB 3 MA 3 MD // MA MB MC MD MT MI // MT MI MF MT CU // CF CW No. of Pt's = 23

*Slashes indicate date changes.

At the beginning of each daily session the student repeated the initial problem type completed at the close of his last session. Thus, the same problem type commonly occurred twice in sequence--before and after a change in date. The number of problem types encountered each day was noted, and the sum of daily counts for the lesson or for the week was recorded as shown in Table 26.

The information about student responses provided in the weekly reports was useful in answering the following general questions:

1. Did the student understand the types of responses expected of him?
2. Did the student attend to the task presented him?
3. Did the student experience visual-muscular coordination problems while trying to respond?

Student responses were catalogued into one of four categories: correct responses; anticipated wrong responses, unanticipated or unknown responses; and overtime responses. The fourth category described responses made after the allotted time for the problem type.

The distribution of both overtime and unknown-answer responses suggested different types of difficulties. For example, if a student consistently made strings of unknown responses, it was assumed that he had difficulty either with muscular coordination or with understanding directions. Similarly, extensive strings of overtime responses suggested that the student did not attend to the task presented him or, again, that he did not understand the instructions. Each week the proctors received distributions of overtime and unknown responses for each lesson within the week. The distribution of overtime and unknown responses was also sorted for three of the major blocks within the curriculum (word list, matrix, and comprehension) as shown in Table 27.

Insert Table 27 about here

The optimization routine used in some of the major blocks provided a method to correct and repeat each of the problems missed by a subject until the response to each problem was achieved without assistance. To determine whether or not this procedure facilitated learning, the ratio of the number of original problems missed to the total number of times the problem was attempted was computed. If this ratio was 1.00, the student learned with one correction on each problem. Values less than 1.00 indicated that, on the average, the student required more corrections for each original problem missed (e.g., .5 indicated two trials per problem). This ratio was computed, printed, and labeled the coefficient of interaction.

In addition to the coefficient of interaction, the percentage correct on the first unassisted trial for each problem within a problem type was computed and printed. This computation did not consider any

TABLE 27

Distributions of Strings of OT's and UU's, Brentwood Reading

Weekly Report

Student Number - Name

J104 John Cannon

Block	S(OT)[1]/S(C+K+W)[2]	Distribution of Strings of OT's[3]							S(UU)[4]/S(C+K+W)	Distribution of Strings of UU's[5]						
		1	2	3	4	5	6	Other		1	2	3	4	5	6	Other
(ALL)	37/305	22	4	1	1	0	0	0	33/305	13	5	2	1	0	0	0
WX	7/47	5	1	0	0	0	0	0	2/47	2	0	0	0	0	0	0
MX	21/103	10	2	1	1	0	0	0	24/103	8	3	2	1	0	0	0
CX	12/78	3	1	0	0	0	0	0	7/78	5	2	0	0	0	0	0

[1]S(OT) = Sum of overtime responses

[2]S(C+K+W) = Sum of all identifiable responses: correct (1), correct (2), incorrect.

[3]OT = Overtime responses

[4]S(UU) = Sum of unknown responses

[5]UU = Unknown responses

responses made while the student was assisted through the correction procedure. Two additional values were computed and printed: (a) the number of problems in the problem type; and (b) the overall proportion correct on the unassisted trials. Table 28 shows these computations on a weekly report for a typical student.

Insert Table 28 about here

Daily report. Data from the daily reports for 1967-68 were assembled to show the relation between the amount of time a student spent on the computer to his progress through the curriculum, which was measured by the number of problem types completed (e.g., screening test, word block, matrix block, sentence initiators, compound words, contractions). A measure of the problem types completed gave a more accurate evaluation of a student's rate of progress, since the problem types covered more nearly equal units of curriculum than did the lessons. A single lesson contained from 4 to 20 different problem types, and a problem type was counted only once. Thus, when a student repeated any part of the curriculum, those repeated problem types were not added to the total of problem types completed. Only main-line problem types were counted; remedial problem types were not considered.

From these daily reports, a weekly summary was compiled that provided the following information for each child: (a) number of minutes on the computer during the week; (b) cumulative time of the computer to date; (c) lesson and PT completed at the end of each week; (d) total PT's completed to date; (e) number of PT's completed during the week.

Figure 22 indicates the progress of three selected students from October 13, 1967 to March 15, 1968. N5 is the student who progressed

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Insert Figure 22 about here

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the farthest. M1 made moderate progress, and J1 showed the least progress. In each case, the line representing rate of progress approximates a straight line. A noticeable change in the rate of progress (slope) was noted as the student moved into Level II (PT 160). The increase in rate shown by J1 at about 600 minutes probably was explained by the practice of proctoring students through the matrix block after they had been working on a matrix block for 2 consecutive days. The data indicate that student rate of progress during this reporting period essentially was linear.

TABLE 28

Computational Information,
Reading Project

Weekly Report

Student Name - Number

J104 John Cannon

No. of problems	Initial per cent correct	Interaction coefficient	Overall per cent correct
N1(WA) = 7	PC1(WA) = 5/ 7 = 0.714	K(WA) = 2/ 3 = 0.667	PC(WA) = 7/ 10 = 0.700
N1(WP) = 7	PC1(WP) = 6/ 7 = 0.857		
N1(WC) = 7	PC1(WC) = 2/ 7 = 0.285		
N1(WN) = 7	PC1(WN) = 7/ 7 = 1.000	K(WN) = 0/ 0 = 0.000	PC(WN) = 7/ 7 = 1.000
N1(WP) = 6	PC1(WP) = 6/ 6 = 1.000		
N1(WC) = 7	PC1(WC) = 4/ 7 = 0.571	K(WC) = 3/ 6 = 0.500	PC(WC) = 7/ 13 = 0.538
N1(GB) = 27	PC1(GB) = 8/ 27 = 0.296		
N1(MT) = 9	PC1(MT) = 3/ 9 = 0.333		
N1(MT) = 9	PC1(MT) = 4/ 9 = 0.444		
N1(MI) = 7	PC1(MI) = 5/ 7 = 0.714	K(MI) = 2/ 3 = 0.667	PC(MI) = 7/ 10 = 0.700
N1(MF) = 7	PC1(MF) = 4/ 7 = 0.571	K(MF) = 3/ 4 = 0.750	PC(MF) = 7/ 11 = 0.636
N1(MT) = 9	PC1(MT) = 7/ 9 = 0.778	K(MT) = 2/ 2 = 1.000	PC(MT) = 9/ 11 = 0.818
N1(CU) = 9	PC1(CU) = 7/ 9 = 0.777		
N1(CF) = 6	PC1(CF) = 1/ 6 = 0.166		
N1(CW) = 9	PC1(CW) = 7/ 9 = 0.777		

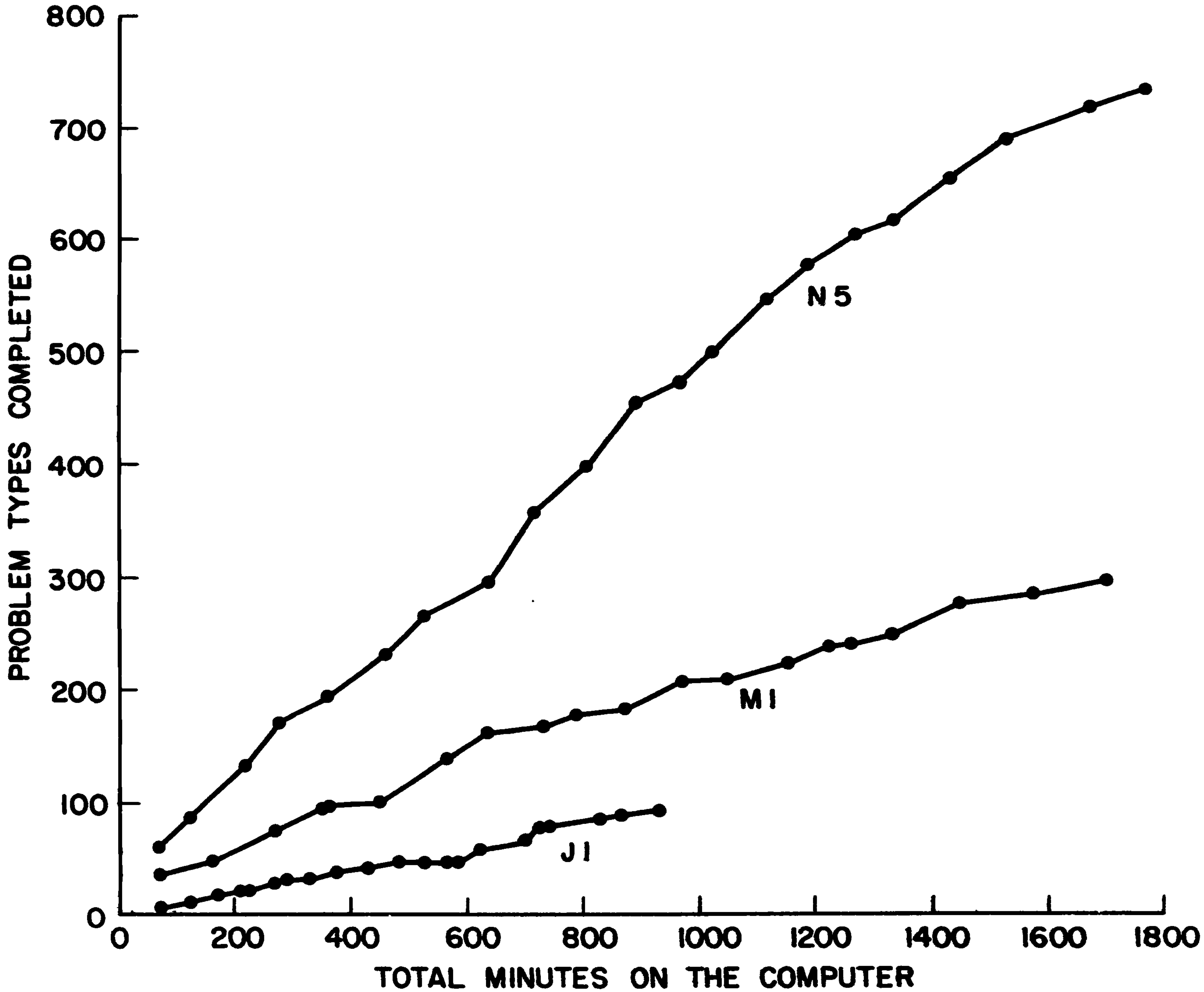

Fig. 22. Weekly Progress of Three Students Through the Reading Curriculum, October 13, 1967 to March 15, 1968

The scatter diagram shown in Figure 23 locates each student by the time he has spent on the computer and by his progress through the curriculum. The diagonal lines from the origin indicate progress rates

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Insert Figure 23 about here

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in minutes per problem type. Eight students progressed at a rate faster than 3 minutes per problem type. The median rate was about 6 minutes per problem type. About 20 per cent of the pupils progressed at a rate slower than 10 minutes per problem type.

Figure 24 indicates the average time efficiency of the system. In computing the average time spent on the computer per day, the number of

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Insert Figure 24 about here

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minutes spent on the computer for each session was totalled for the week and divided by the number of student days; 2 minutes or more of work was counted as a student day. Days when the student was off-line for remedial help and days when machine failure resulted in no time on the computer were not counted. Figure 24 indicates the time efficiency of the system to be about 70 per cent with a range from 50 to 80 per cent. Time was lost through machine failure during a session, lesson turn-around time, and interruptions for discipline or explanation.

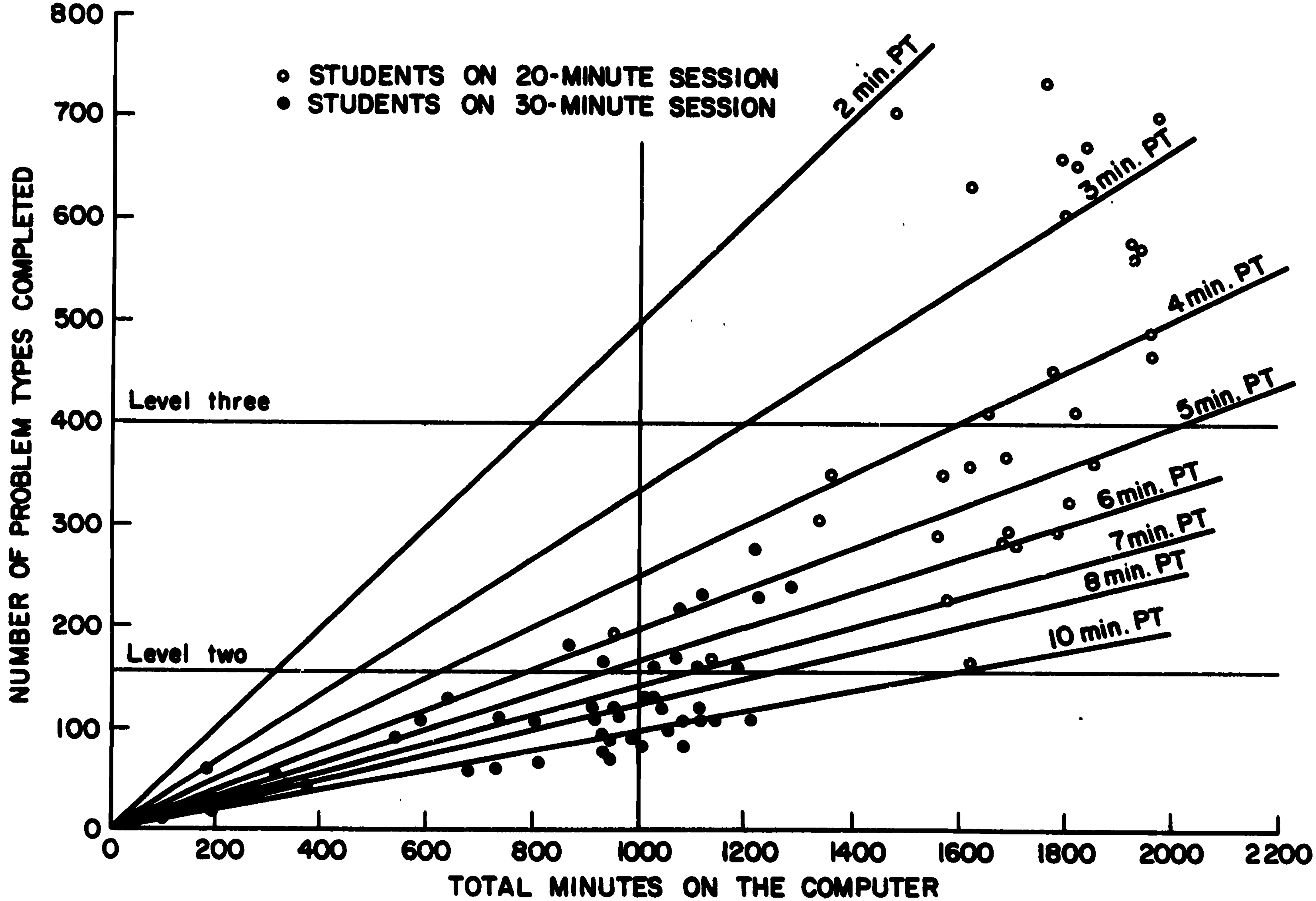

Fig. 23. Distribution of Students by Reading Lesson Material and Time on Computer as of March 15, 1968

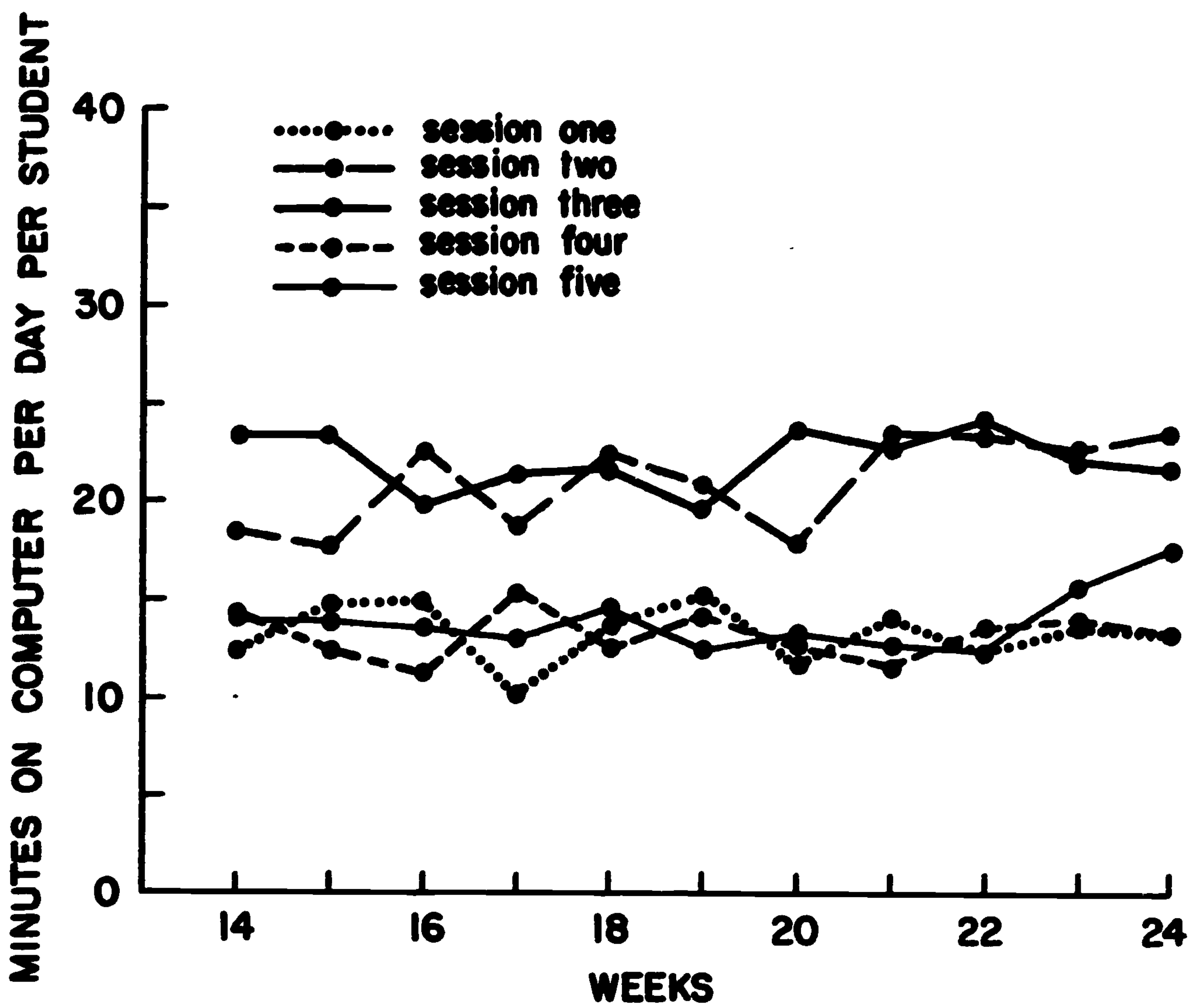

Fig. 24. Average Time on Computer per Student for each Reading Session

Chapter 5

Dissemination of Information

Three means of information dissemination evolved during the period of the contract: (a) publications and lectures; (b) films; and (c) visitors to the Laboratory. It should be pointed out that the total area of dissemination came about solely by public demand, and not by the Institute seeking publicity.

5.1. Publications and Lectures

Staff members at the Institute wrote a large number of articles for publication as technical reports, for publication in scholarly journals and popular magazines; they also gave lectures and participated in panel discussions and conferences throughout the nation and the world. Appendix 3 gives a listing of publications and lectures.

5.2. Films on the Stanford-Brentwood Project

In accordance with Amendment 1 which extended the period of the contract from June 30, 1967 to December 31, 1967, three films were produced about the Stanford-Brentwood Computer-assisted Instruction Laboratory, and presently available through the Institute for Mathematical Studies in the Social Sciences are the following:

"The Brentwood Project," a 14-minute, 16mm color-sound film devoted exclusively to the Stanford-Brentwood CAI Laboratory, was produced by an Institute staff member in the Communication Department at Stanford University. The film presents a thorough survey of the laboratory operation, the mathematics and reading curricula, the computer system and its function, lesson preparation, the role of proctors, and evaluation of data.

"Please Type Your Name," a 14-minute, 16mm color-sound film produced for the Institute by Davidson Films of San Francisco, is an overview of CAI through research projects conducted by the Institute. The film gives brief descriptions of the teletype logic program, the McComb mathematics project, the computer-assisted Russian course at Stanford University, and the Stanford-Brentwood CAI Laboratory.

"Computers in the Classroom," a 5-minute, 16mm color-sound film produced by ABC for the IBM Corporation, is a very brief description of the Stanford-Brentwood Laboratory, and includes a short interview with Professor Patrick Suppes.

These films were (a) used to supplement talks given by staff members; (b) sold to interested individuals and institutions at cost; (c) loaned to individuals and institutions for a nominal fee, and loaned to television stations for broadcast; (d) duplicated at cost for film and television producers to use in documentaries about CAI.

5.3. Visitors

The number of visitors to the Laboratory from January to December, 1967 demonstrated an increased awareness of the project by the public, professional educators, and news media throughout the nation and the world. Owing to the limited viewing area and the large number of visiting requests, it was necessary to preschedule all visits. Generally, groups were limited to 10 persons. In order to accommodate the wide range of interests (from data reduction to curriculum details), it was necessary that various Institute staff members be on hand to insure the dissemination of accurate and authoritative information.

A special terminal equipped with a loudspeaker audio output served as a demonstration unit for small groups. Visitors during the mathematics instructional time were allowed to work through lessons actually on-line for the children. Multiple lessons also were available so that the visitor was able to view different sections of the instructional program.

Visitors who appeared during the reading instructional sessions received a special overview demonstration lesson on CAI reading curriculum. The following is an abstract of that course.

NAME: READ1-52 (Code Name: BZ)
TIME: 10 minutes to over two hours (user determined)
LENGTH: 240 sectors on an IBM 2315 disk pack (about 7,000 instructions)
MACROS: 52
FUNCTIONS: 7
AUDIO MESSAGES: 335 (1-20 seconds; many segmented audios)
FILM FRAMES: 26
GRAPHICS: 41
FREE-CHOICE POINTS: 26 (some may be encountered more than once)
SECTIONS WITHIN THE LESSON: 21, including major sub-sections; otherwise, 17
RESTART POINTS: 1
TERMINAL EQUIPMENT: CRT with light pen, rear-image projector, audio headset
MODE OF RESPONSE: Light pen (multiple choice)
TOTAL PREPARATION TIME: Four months
AUTHORS: David McMullen and Karl Anselm

This learner-controlled program described and demonstrated numerous capabilities of CAI: branching; student feedback; functions; graphics; and proctor calls. It used the following terminal equipment: cathode-ray tube (CRT); light pen; image projector; and audio unit.

The program, a demonstration reading lesson, provided an overview of the initial reading curriculum used with first-year students. The lesson followed the format of actual CAI reading programs.

After assistance in signing on, the user required no outside help. No knowledge of computers, the reading curriculum, or previous acquaintance with CAI was assumed or was necessary to use this program. The course was intended for parents, classroom teachers, curriculum writers, researchers, and computer personnel, as well as others interested in this mode of instruction.

The basic outline of the course was as follows:
Welcome: demonstrated use of the light pen and audio system
Day 1: demonstrated graphics and answering on the CRT
Day 2: demonstrated correction procedures and the image projector
Day 3: letter-teaching sequences
Introduction: standard lesson outline
Word Block: initial teaching of words and optimization routine
Poem: demonstrated intonational material
Matrix: major device for presenting linguistic patterns
Screening Test: the standard beginning for a lesson
Game: adapted baseball to reading instruction
Doggerel: introduced comprehension section
Usage: comprehension as understanding definitions
Form-Class: comprehension as correct use of syntax
Who-What: comprehension as ability to answer questions
Reading Story: read by student (audio as needed)
Polysyllabic Section: demonstrated teaching of two-syllable words
Conclusion: allowed user to return to beginning of lesson and review.

Unlike a child's lesson, the user was able to choose sections of a lesson he wished to see. Before each section, he was given an opportunity to bypass a section or to continue through it. At the end of the lesson, the user was able to return to the beginning of the lesson and then to bypass material until he came to a section he wished to review. The one restart point at the beginning of the lesson enabled the user to sign off at any time and to sign on at the start of the program. The course proved particularly valuable through its inclusiveness and user-control aspect.

System records were kept of those who have visited the Laboratory. A complete list of visitors during January 1 through March 31, 1967; October 1 through December 31, 1967; and January 1 through March 31, 1968 is included in Appendix 4, together with a list of the foreign countries represented.

In addition to regular visitors, several filming groups visited the Laboratory. A KQED-TV "Education in Motion" series presented a program on the relationship of the Laboratory to the classroom teacher's program. The KQED-TV "Do You Read Me?" series presented a program on innovative instructional procedures developed at Brentwood for the teaching of reading. An IBM documentary team showed the relationship of the equipment to the instructional program; and Information Management Facilities, Inc., prepared a film sequence of children working with the terminal equipment, which was used in an IBM seminar and then was made available to groups from many fields, including education, science, industry, the arts, government, and religion.

During the second year of operation, public opinion gradually changed from one of concern of replacing teachers by this technology to an interest in its proven feasibility, its successes, and implications for school systems preparing for a future which included computer-assisted instruction.

Chapter 6

Conclusions

The main objective in developing a computer-assisted instruction program in mathematics and initial reading was to individualize instruction so that each child could progress through a subset of materials best suited to his particular aptitudes and abilities at his own pace. For the first time a school-based laboratory was established to conduct curriculum research and to evaluate under controlled conditions the acquisition and retention processes involved in mastering reading and arithmetical skills.

The theory of instruction developed at Brentwood through experimentation with the mathematics and reading programs can, with proper constraints, be generalized to other programs, such as elementary science and beginning work in foreign languages. This theory of instruction attempts to optimize the learning situation by manipulating variables such as content, nature and sequence of presentation, to provide the best learning environment for each individual child. To achieve individualization, a means for determining the best future program of instruction for each child based on the history of his past responses was required. Thus, presentation of materials for each child was controlled by correctness of his past responses, the length of time he took to make them, and the nature of his past learning patterns.

In the mathematics program, the tutorial system assumed the main responsibility for presenting a concept and for developing skill in its use. As soon as a child understood a concept by successfully working a number of exercises, he was introduced to a new concept and new exercises. If he faltered or made incorrect responses, he immediately was branched to remedial problems. The aim of the system was to approximate the interaction a patient tutor would have with an individual student; thus, every effort was made to design a curriculum flexible enough to avoid boring the brighter children with too many repetitive exercises and to avoid the experience of failure for the slow students.

The 400 first-grade lessons included topics on counting, numerals, addition, subtraction, linear measure, as well as sets and set notation, congruence of plane figures, and some oral story problems. The average lesson contained fewer than 10 problems, and generally, all problems were of the same type. Students had to achieve a preset criterion of correct responses for each lesson (e.g., 7 out of 9, 6 out of 8, 8 out of 10). When the student responded correctly to the required number of problems, he was allowed to skip the remaining problems and to begin the next lesson. If he failed to meet criterion, he was branched immediately to a remedial lesson, bypassing the remaining problems in the lesson. The remedial materials contained the same kinds of problems, but developed the ideas at a slower pace using simpler vocabulary and sentence structure.

Individualization of instruction was achieved, therefore, by the following means.

1. Providing an immediate response to each answer.

2. Organizing problems in terms of difficulty.

3. Selecting individual review lessons.

4. Permitting students to progress at their individual rates through the curriculum. (In a tutorial setting what is presented at the console is not necessarily tied to classroom work.)

5. Providing a varied curriculum for each child. Bright students bypassed the remedial loops and maintenance blocks of skills were given only to students whose pretests indicated such a need.

At various intervals during the year, it was necessary to work with the children in the classroom rather than in the terminal room. Classroom activities included: (a) use of physical objects to introduce concepts presupposed by programmed lessons; (b) augmented work originally planned as programmed lessons; (c) remedial work for individual children; and (d) enrichment material for individual or groups of children.

The differences in rates of learning were sharply evident. After eight days on-line at the beginning of the semester in September, 1967, the spread of children was from Book 1 through Book 5. At the end of December, 1967, the spread was from Book 6 through Book 19. Those children who completed the most books, of course, spent very little time on remedial problems; those children who completed the fewest books spent a great deal of time on remedial work.

The Individual Stanford Binet I.Q. Test (short form) was administered to 100 students in the fall of 1966, and in the following spring, the same group was given the Stanford Achievement Test, Primary I Battery, Form W. Half of the group served as the experimental group for the mathematics computer-assisted program and the other half (the experimental group for the initial reading program) served as the control group. Further, of two classes in the experimental group and two classes in the control group, one class in each group was of average ability and one class in each group was of below-average ability. There was no significant difference in performance for the I.Q. tests between the experimental and control groups. Data compiled from the SAT scores, however, indicated that the mean performance of the experimental group was superior to the control group, although the difference was not statistically significant. On the other hand, in comparing the two classes of below-average ability, the difference between the experimental class and the control class was highly significant statistically and in favor of the experimental group.

Within the average I.Q. group, the girls in the experimental group performed significantly better on the SAT than the girls in the control group. Within the low I.Q. group, the boys in the experimental group performed significantly better than the boys in the control group. There were no significant differences between the performances of boys and girls. In conclusion therefore, the data indicated that the students who seemed to benefit most from computer-assisted instruction were boys with a low-measured I.Q. and girls with an average-measured I.Q.

Hypotheses about the reading process and the nature of learning to read were formulated on the basis of linguistic information, observations of language usage, and an analysis of the function of the written code.

Over 200 lessons divided into eight levels were written. The average student progressed through a lesson in about 30 minutes; a bright student could cover certain lessons in 10 minutes or less; a slow student might require two hours or more if he were branched through most of the remedial material. The instructional tasks within a lesson were divided into three broad areas: (a) decoding skills (letter and letter-string identification, word-list learning, phonic drills); (b) comprehension (direct recall of facts, generalization about main ideas in a story, inferential questions requiring the child to relate information presented in a story to his own experience; and (c) games and other motivational devices (games sequenced into the lessons to encourage continued attention and devices structured to evaluate the developing reading skills of the child).

Students had to exhibit mastery of a central core of about 125 main-line problems within each lesson. Main-line problems were bypassed by passing certain screening tests or by making correct responses. Incorrect responses branched the student to remedial material. Thus, the number of lessons completed was used as an index for the number of main-line problems completed successfully. At the end of the first year, the range in rate of progress was between 35 problems per hour for the slowest student to 170 problems for the fastest student. From the standpoint of both the total number of problems completed and the rate of progress, CAI reading curriculum seemed to account for individual differences on at least one dimension (i.e., movement of the individual student through the lesson material). The differences are not to be confused with a variation in the rate of response--that difference was very small. The average rate was approximately four responses per minute and showed very little variation over students. The differences in the total number of main-line problems completed and in the rate of progress was laid to the amount of remedial material necessary and the number of accelerations for different students.

Reading studies generally indicate that girls surpass boys in the acquisition of reading skills and in reading performance, particularly in the primary grades. In order to test this notion, the rate-of-progress scores were evaluated statistically for sex effects. The results of this analysis indicated that scores for both boys and girls showed the same distribution. These data tended to support the notion that when students moved from the usual classroom social environment to a CAI tutorial environment, boys performed as well as girls at an overall rate of progress. Girls did score higher than boys, however, in the word-list section, which was essentially a paired-associate learning task.

Posttest results were compiled from two groups of first graders. One group received CAI reading instruction and the other group received CAI mathematical instruction and was used as the control group for the reading group. Both groups were given conventional achievement tests before the project began and again late in the spring. While the scores for the two groups were not far apart on the pretest, the group that received CAI reading instruction performed significantly better on most of the reading posttests. For example, on the California Achievement Test, the CAI reading group scored 7.6 points above the CAI mathematics group.

When the reading program first began, students were run for a brief period each day on the terminals. After six weeks, the time was increased to 20 minutes and in the last month students were allowed to work on the terminals from 30 to 35 minutes. The first-grade children adapted very well to longer periods of time on the terminals, and in the future, each student will run at least 80 to 90 hours during the year on the terminals.

Although much data remained to be analyzed, the work done can serve as the basis of a theory of individualized instruction to span the diversity of concepts and skills found in elementary-school subjects such as mathematics and reading.

Appendix 1

Outlines of First-Grade Mathematics Curriculum, 1966-67

The outlines are constructed as follows:

Lesson Concepts. Under this heading are the lesson labels (A, B, etc.), purpose of the lesson, a brief description of a typical problem, and the number of choices involved. Lessons with accompanying visual displays on the film screen are indicated by "film display."

Lesson. In this column are the number and type of problems in the lesson. In Lesson 1A, for example, "0 + 5" means that there were no explanation problems and 5 practice problems. There was a 4/5 criterion. (Note that only practice problems are considered in the criterion.) The letters KA indicate a special case in which a student who has clearly passed criterion must do all problems in a lesson. (The letters KKA, as in Lesson 3F, indicate that a student who is failing criterion must complete the lesson.)

Several lessons and branches (e.g., the branch for Lesson 7A) have more than one criterion block. In these lessons, students must successfully complete each block before proceeding to the next.

Branch. Number of explanation and practice problems together with the criterion in the remedial branch.

Mode. "P" refers to probe or light pen. All light-pen lessons are in multiple-choice format. "K" refers to keyboard. All lessons in this mode require a constructed response.

Books 11, 12, and 13 were not programmed and hence are not included in the outlines.

BOOK 1 PURPOSE: Using the machine

LESSON CONCEPTS	LESSON		BRANCH		MODE
	L	L	B	B	P
LESSON A. How to use the light pen. "Touch Mr. Bunny with your light pen; push it till it goes click."	0 + 5	4/5 KA	0	0	P
LESSON B. Following the arrow with light pen. "The arrow shows you the rooster. Touch the rooster with your light pen."	1 + 5	4/5	0	0	P
LESSON C. Understanding the "p" as a "ready light"; arrow as clue to the right answer. "Wait for the ready light. Then touch the picture the arrow shows you."	0 + 6	5/6	0	0	P
LESSON D. Game with the "magic light pen." "Point to the dog with your light pen and see what happens."	2 + 6	5/6	0	0	P
LESSON E. Test aural comprehension of the word "top"; happy or sad face for positive or negative reinforcement. "here are a lion and a giraffe. Point to the picture at the top. The happy face tells you you're right. The sad face tells you you should try again." 2 choices	2 + 5	4/5	2 + 4	3/4	P
LESSON F. Test aural comprehension of the word "bottom." "The teddy bear is at the bottom. Point to the teddy bear." 3 choices	1 + 5	4/5	0	0	P
LESSON G. Test aural comprehension of the word "middle." Review "top" and "bottom." "The kangaroo is in the middle. Point to the kangaroo." 3 choices	2 + 7	6/7	0	0	P
LESSON H. A picture is displayed on the left side of scope. Student chooses same picture from group below. Picture appears opposite given picture on right side of scope. "Suzanne has a camel. Point to the camel below so Mickey can have the same thing." 3 choices	2 + 9	7/9	0	0	P

BOOK 2A PURPOSE: Sets

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Pointing to members in sets. "Here is a set of things. Point to the truck in the set." 5 choices	0 + 5	4/5 KA	0 + 5	4/5 KA	P
LESSON B. Introduce vocabulary "braces" and "members." Pointing to braces and members. "Braces tell us here is a set. Point to a brace." "The things in a set are called members of the set. Point to a member in this set."	6 + 6	5/6 KA	6 + 5	5/5 KA	P
LESSON G. Introduce the answer-box format. Choosing "the same" figure. "I have an animal on my side of the scope. Point to the box that goes with the same animal below so that you will have one on your side." 3 choices	0 + 7	6/7			P
LESSON C. Practice using the answer box with riddles. "Point to the box next to the picture which answers the riddle." 3 choices	1 + 6	5/6			P
LESSON D. Distinguishing sets by naming one or more members or common properties of members; pointing to answer box next to sets. "Find the set whose members are things to eat. Touch the box next to this set." 3 choices	1 + 4	3/4	3 + 4	3/4	P
LESSON E. Introducing the empty set. "Nothing's shown between these braces. It is an empty set. Point to the box next to the empty set." 2 choices	4 + 6	5/6	2 + 4	3/4	P
LESSON F. Distinguishing the empty set. "Find the picture of the empty set." 3 choices	0 + 4	3/4	0 + 7	5/7	P

BOOK 2B PURPOSE: Matching equal sets.

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON H. Matching equal sets. "Find the set that is the same as the set at the top of the scope." 2 choices	4 + 7	6/7	2 + 6	5/6	P
LESSON I. Introducing the equal sign with equal sets. A = ___. "Which of the sets below is equal to the set at the top of the scope." 2 choices	8 + 7	6/7	6 + 6	5/6	P
LESSON J. (Drill Practice.) in matching sets. "Find the set that is equal to the set at the top." A = ___. 3 choices	0 + 7	6/7	3 + 6	5/6	P

BOOK 3A Union of two sets with one member.

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Learning the written words "yes" and "no." "Is this a cow? Point to the box that goes with 'yes'." (film display)	2 + 6	5/6	4 + 6	5/6	P
LESSON B. Story - Practice in counting 1 to 5; answering with yes and no. (film display) "Do you see three chickens on the screen?"	0 + 10	7/10 KA			P
LESSON C. Union of sets without the equal sign. Introducing the U sign. "The set of the apple in union with the set of the peas gives us what new set?" 2 choices	5 + 10	8/10	7 + 8	6/8	P
LESSON D. Expressing union of sets in the form of an equation. Dotted line as space for answer. A U B = ___. "Which set goes on the dotted line?" 2 choices	6 + 10	8/10	12 + 7	6/7	P
LESSON E. Review of union of sets, 3 choices	1 + 7	6/7	2 + 6	5/6	P

BOOK 3B Union of empty sets

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON F. Drill - Counting on scope with "yes" and "no" answers. 2 criteria blocks in lesson.	4 10	4/4 8/10 KKA			P
LESSON H. Union of sets with the empty set. "The set of toys in union with the empty set equals which set?" 2 choices	5 + 10	8/10			P
LESSON I. Union of sets with the empty set. 3 choices	4 + 7	6/7	3 + 6	5/6	P
LESSON J. Union of two or more sets. 3 choices	1 + 7	6/7			P
LESSON K. Drill - Equal sets. "Find the set equal to the set at the top." 2 choices	0 + 10	8/10			P

BOOK 4 Geometry - Learning to identify squares, circles, triangles and line-segments.

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Introduce answer-box format with film displays. "At the top of the picture screen is a picture of a car. At the bottom is a picture of a boat. Look at the scope. The box goes with the boat. Point to the box that goes with the boat." 2 choices, film display	2 + 4	3/4	4 + 6	5/6	P
LESSON B. Practice answer-box format with film display. 3 choices, film display.	2 + 8	6/8	5 + 6	5/6	P
LESSON C. Introduce squares; counting squares. "On the screen are some squares. All squares have 4 corners. Point to the box on the scope nearest the row with 5 squares in it." 2 choices, film display.	0 + 7	6/7			P
LESSON D. Distinguishing squares from other figures. "There are three figures on the screen. Point to the box on the scope nearest the square." 3 choices, film display.	4 + 9	7/9	3 + 8	6/8	P
LESSON E. Introduce circles; counting circles. "On the screen are some circles. All circles are round. Point to the box on the scope nearest the row with 2 circles in it." 2 choices, film display.	0 + 7	6/7			P
LESSON F. Distinguishing circles from other figures. "There are three figures on the picture screen. Point to the box on the scope nearest the circle." 3 choices, film display.	4 + 9	7/9			P
LESSON G. Introduce triangles; counting triangles. "On the picture screen you can see some triangles. All triangles have 3 pointed corners. Point to the box on the scope near the row with 4 triangles in it." 2 choices, film display.	0 + 7	6/7			P

BOOK 4

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON H. Distinguishing figures with 3 pointed corners from other figures. "There are 3 figures on the screen. Point to the box on the scope nearest the figure with 3 pointed corners." 2 and 3 choices, film display.	2 + 7	6/7	3 + 8	6/8	P
LESSON I. Distinguishing triangles from other figures. "On the screen there are 3 figures. Point to the box on the scope that goes with the triangle." 3 choices, film display.	3 + 9	7/9			P
LESSON J. Introduce line segments; counting line segments. "On the screen are some line segments. Point to the box on the scope that goes with 4 line segments." 2 choices, film display.	0 + 7	6/7			P
LESSON K. Distinguishing line segments. "On the screen are some figures. Point to the box on the scope that goes with the line segment." 4 choices, film display.	3 + 9	7/9			P
LESSON L. Drill - Equal sets. "Find the set equal to the set of the boy and the dog."	0 + 10	8/10			P

BOOK 5 Balancing set equations

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Union of sets. A = ___. "Look at the top set. There are a candle and a flower in the top set. Find the sets we can put together to get the top set." 3 choices	2 + 7	6/7	5 + 6	5/6	P
LESSON B. Union of sets with empty sets. A = ___. "The set at the top is equal to the union of which two sets?" 3 choices	2 + 4	4/4	2 + 3	3/3	P
LESSON C. Lesson counting pennies. "On the screen are two rows of pennies. Find the box on the scope that goes with the row that has six pennies." 2 choices	2 + 7	6/7 KKA			P
LESSON D. Union of sets; dotted line on either side of the equal signs. AUB = ___, ___ = AUB. "If you put together all the sets at the top, which set do you get?" 3 choices If proctor call, go to next book.	3 + 9	7/9	1 + 11	8/11	P
LESSON E. Union of sets - balancing set equations. AU __ = C. "Which set can we put together with the candy cane to get the set of the candy cane and the ice cream cone?" 3 choices If proctor call, go to next book.	2 + 7	6/7	3 + 6	5/6	P
LESSON F. Union of sets - balancing set equations. __ U B = C. "Find the set we can put together with the set of the wagon to get the set of the wagon and the leaf." 3 choices If proctor call, go to next book.	1 + 6	6/7	3 + 6	5/6	P
LESSON G. Union of sets - mixed drill. A U B = ___, ___ U B = C, A U ___ = C. 3 choices. If proctor call, go to next book.	1 + 7	6/7	2 + 6	5/6	P

BOOK 6A PURPOSE: Introducing the numerals 0, 1 and 2.

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Choosing sets by counting members (one through four). "Which set has 3 members?" 2 choices	6 + 7	6/7	3 + 8	6/8	P
LESSON B. Aural comprehension of the word "zero." Finding the set with zero members. "Zero means nothing. Point to the set with zero members." 2 choices	2 + 4	4/4	2 + 4	5/6	P
LESSON C. Choosing sets by counting members (zero through four). 3 choices	1 + 12	9/12	5 + 8	6/8	P
LESSON D. Introducing numerals 0 and 1. "There is one thing in this set. Point to the numeral one."	2 + 4	4/4	2 + 3	3/3	P
LESSON E. Introducing numeral 2. "There are two things in this set. Where's the numeral two?" 3 choices	4 + 5	4/4	1 + 3	3/3	P
LESSON F. Practice with numerals 0, 1 and 2. "Count the things in the set and find the right numeral." 3 choices	1 + 7	6/7	0 + 3 (br1) 0 + 6 (br2)	3/3 5/6	P
LESSON G. Finding another set with the same number of members (0 - 4). "There are three members in this set. Find another set with the same number of members." 2 choices	4 + 9	7/9	5 + 8	6/8	P
LESSON R. A game in which child uses light pen to choose the same number of members as one in a given set. "I have two (things) in my set and you have zero members in yours. Point to the members you want in your set so you will have as many as I do."	2 + 10	8/10			P

BOOK 6B PURPOSE: Introduce N Notation with equivalent numerals. Introduce 3 and 4.

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON H. Introducing N notation. Child chooses a set of things that has the same number of members (0 - 4) as the given set. "The number of things in the set of people is the same as what?"	3 + 4	4/4	2 + 6	5/6	P
LESSON I. N notation with numerals. "The number of things in the set equals what? Point to the right numeral." (0 - 2) 3 choices.	6 + 7	6/7	3 + 6	5/6	P
LESSON J. Drill with N notation and numerals. "The number of things in the set is what?" 3 choices - 2 in branch	0 + 7	6/7	2 + 6	5/6	P
LESSON K. Introducing numerals 3 and 4 with N notation. 3 choices, 0 - 4.	4 + 7	6/7	8 + 6	5/6	P
LESSON L. Preparation for addition. Story of Pablo and his friend. "Just then they heard sirens and saw two big fire trucks hurry past. Then one more went by. How many were there all together? Point to the answer." 5 choices, numerals 0 - 5 displayed on scope. Objects on film.	0 + 10	7/10 KKA			P
LESSON M. N notation and numerals 0 - 4. Blank for numeral on left side of equal sign. 3 choices	4 + 7	6/7	3 + 8	6/8	P
LESSON N. N notation and numerals 0 - 4. "Find another name for 2." (blank on either side - fill with equivalent set or equivalent numeral.) 3 choices	2 + 10	8/10	4 + 11	8/11	P
LESSON O. Using the Keyboard. Typing numerals 0 - 9. "The arrow points to zero at the top of the scope. Look for the key with a zero on it. Push the key with your finger. Good. The numeral zero shows on the scope."	7 + 4	4/4	5 + 6	5/6	K

BOOK 6B

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON P. Typing counting marks. A numeral is shown on the scope. Child types equivalent number of counting marks. (1-4)	9 + 7	6/7	10 + 6	5/6	K
LESSON Q. Counting taps given orally and typing the equivalent numeral. (1-4)	2 + 7	6/7	0	0	K

BOOK 7A PURPOSE: Sums with N Notation (0-4)

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. N notation with equivalent counting marks. "Here is a name for 3. Three marks go with this name. Here is another name for 3. But this picture is wrong. It has only two marks. Point to the box that goes with the name that has the right number of marks." 2 choices. 3 criteria blocks in branch.	5 + 9	7/9	0 + 5 2 + 6 2 + 8	4/5 5/6 6/8	P
LESSON B. Sums with N notation. First use of the plus sign. Counting marks used as aid in finding the correct answer. "One thing and two things are how many things? Point to box that goes with the correct answer. The counting marks will help you find the answer." 2 choices	6 + 7	6/7			P
LESSON C. Naming and distinguishing plus sign in equations with N notation. "This sign says to put numbers together [+]. It is called a plus sign. Point to the plus sign with your light pen."	0 + 7	6/7			P
LESSON D. Sums with N notation. Counting marks as aid in finding correct answer in tol. (0-4) 2 choices	3 + 10	8/10			P
LESSON E. Counting Drill - distinguishing seven objects from 1-6 and 8. 3 choices	1 + 10	8/10 KA			P
LESSON F. Review of numerals (0-4) with N notation. Counting marks with numerals as aid in tol to2 and wa. 2 choices. 2 criteria blocks in branch.	0 + 12	9/12	0 + 6 0 + 6	5/6 5/6	P

BOOK 7B PURPOSE: Sums with numerals. Keyboard responses. (0-4)

LESSON CONCEPTS	LESSON	BRANCH	MODE
LESSON G. Numerals and N notation without counting marks. (0-4) 3 choices	3 + 10	8/10	P
LESSON H. Sums in N notation with numeric equation displayed below. (no counting marks) "Find the correct numeral to put on the dotted line." 2 choices	3 + 9	7/9KA	P
LESSON J. Sums with numerals. (0-4) "Two plus one is how many? Find the correct numeral to put on the dotted line." (2 choices) Counting marks as aid.	3 + 9	7/9 KA	P
LESSON K. Numerals and N notation - typing the numeral. (0-4) ___ = N [a, b, c] "Type the numeral that goes on the dotted line."	3 + 9	7/9	K
LESSON L. Sums with numerals - typing the numeral. (equations) "One plus one equals how many? Type your answer." (Counting marks as aid.)	1 + 9	7/9 KA	K

BOOK 8 PURPOSE: <u>Review</u>

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. <u>Story</u> - Counting objects displayed on screen - distinguishing 7 from 8 and 8 from 9. "On the screen you can see the Indians dancing. Are there eight Indians? Point to the box with yes or no on the scope." 2 choices, film display.	0 + 10	8/10 KKA			P
LESSON B. Review typing counting marks for displayed numerals. (1-4)	0 + 4	4/4 KKA	2 + 4	3/4	K
LESSON C. Review Union of Sets. A U B = ___ and A U B U C = ___. 3 choices.	0 + 10	8/10			P
LESSON D. Addition with numerals. Typing counting marks below addends for sums to four, and then typing the numeral that balances the equation. (graphic numeral)	0 + 12	9/12			K
LESSON E. Addition with numerals. Drill 1. Sums to four. No counting marks. (graphic numerals)	0 + 10	8/10 KKA			K
LESSON F. Addition with numerals. (0-4) Game: The horse on the screen will make it over the jump each time the student finishes the equation on the scope correctly. (graphic numerals, film display). [P.C. if any three out of the first four are wrong]	1 + 10	8/10 KKA			K
LESSON G. Addition with numerals introducing vertical format. Sums to four. $\begin{array}{r} 2 \\ \underline{+\ 2} \end{array}$ "Here is another way to write two plus two. Type the answer." (graphic numerals)	4 + 9	7/9	11 + 8	6/8	K
LESSON H. Counting pennies displayed on screen and typing equivalent numeral on scope. (1-4) (graphic numerals, film display	0 + 10	8/10 KA			K

BOOK 9A PURPOSE: Addition

LESSON CONCEPT	LESSON		BRANCH		MODE
LESSON A. Practice union of sets. Problem and answer choices displayed on screen with answer boxes on scope. 3 choices, film display.	1 + 10	8/10 KA			P
LESSON B. Numerals and N notation - the numeral 5. Review 1 - 4. "Find another name for 5" 5 = ___ = N [a, b, c, d, e] 2 choices.	4 + 10	8/10	11 + 8	6/8	P
LESSON C. Counting objects displayed on screen and pointing to equivalent numeral for each on scope. 3 choices, film display.	0 + 9	7/9	0 + 8	6/8	P
LESSON D. Addition with numerals. Adding one to 0-4. As student completes each problem it is added to a table which appears at the left of the scope. This table of the first five explanation problems and their answers remain on the scope throughout the rest of the lesson for reference. Counting marks as clues in the to and wa of explanation problems. 3 choices.	5 + 7	6/7	0 + 6	5/6	P
LESSON E. Addition with numerals. Adding zero to 0-5. Counting marks as clue after first time out. 2 branches. Table developed and used in first branch.	6 + 9	7/9	6 + 8 9 + 8	6/8 6/8	P

BOOK 9B

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON F. Distinguishing and counting geometrical figures on the screen. (circles, triangles, squares and line segments.) (graphic numerals, film display)	0 + 10	8/10 KA			K
LESSON G. Commutative addition combinations of 1-5 in paired equations. First equation remains on scope until second equation is completed. Counting marks as clues after first time out. "The problem you just did should help you." (graphic numerals)	8 + 5	4/5	7 + 7	6/7	K
LESSON H. Addition combinations of 1-5. Vertical format. (graphic numerals)	6 + 10	8/10	16 + 8	6/8	K
LESSON I. Level Drill 2. 3 levels of criteria blocks.	0 + 10	8/10			K

BOOK 10 PURPOSE: Geometry

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Learning the meaning of "open" and "closed." Screen displays a fence with different farm animals inside, and the gate either open or closed. Student answers questions "Can the rabbits get out of their yard?" "Is the fence open?" - with "yes" and "no" answer boxes on scope. (film display)	4 + 7	6/7			P
LESSON B. Distinguishing open figures. Figure displayed on screen. Student answers question "Is this figure open?" with "yes" and "no" boxes on scope.	3 + 7	6/7			P
LESSON C. Distinguishing closed figures. Three figures are displayed on screen. Student touches box on screen nearest the closed figure. 3 choices.	1 + 7	6/7			P
LESSON D. Review. Distinguishing squares, circles, triangles and line segments. Figures are displayed on the screen. Student answers questions "Which figure is a circle, etc.?" by touching box on scope nearest the named figure.	0 + 10	8/10 KA			P
LESSON E. Learning that squares, circles and triangles are closed figures. "Here are many triangles. Do you think all triangles are closed?" "Yes" and "No" format, film display.	0 + 12	9/12			P
LESSON F. Counting sides of polygons. "Tell how many sides each figure has." Answer boxes on scope. 3 choices, film display	2 + 7	6/7	6 + 8	6/8	P
LESSON G. Introducing rectangles. Counting rectangles. "Point to the box on the scope that goes with the row of three rectangles. 2 choices, film display.	0 + 4	4/4			P
LESSON H. Distinguishing rectangles. "Rectangles are like stretched out squares. Point to the box on the scope that goes with the rectangle." 3 choices film display.	3 + 9	7/9	8 + 8	6/8	P

BOOK 10

LESSON CONCEPTS	LESSON	BRANCH	MODE
LESSON I. Story - Counting. Distinguishing 9 from 6-10. "On the screen are some trained seals. Are there nine seals?" (Yes and No format, objects on film)	0 + 10	8/10 KKA	P
LESSON K. Level Drill. Adding one and zero to 0-3 Five levels of criteria blocks. Blank on left side of equal sign in 5th block. (graphic numeral)	0 + 10	8/10	K

BOOK 14A PURPOSE: Measuring Line Segments

LESSON CONCEPTS	LESSON		BRANCH	MODE
LESSON A. Measuring line segments. There is a ruler displayed on the screen with a line segment just above it. "The segment comes to 2 on the ruler. How many inches long is the segment?" (graphic numerals.)	3 + 7	6/7 KA		K
LESSON B. Measuring line segments. Student brings 3 work sheets and ruler. Measures line segments on work sheet as directed by audio, then types his answer. Displays on screen show how to measure in tol. (graphic numerals)	1 + 9	7/9	KA	K
LESSON C. Measuring line segments in sides of polygons. Student brings ruler and work sheet. 2 figures on each sheet. "Measure the red side of the figure at the bottom" Display on screen as clue in tol. (graphic numeral.)	2 + 9	7/9 KA		K
LESSON D. Level Drill - Addition 0-5. Five levels of criteria blocks. Throughout each block completed equations remain on scope. Blank on left side of equal sign in levels 2, 4, 5.	0 + 10	8/10		K
LESSON E. Story problems - preparation for subtraction. Johnny has three apples. Susie has two apples. How many apples must Susie get so she'll have as many as Johnny. 3 choices, objects on film.	0 + 10	8/10		P

BOOK 14B PURPOSE: Concave Figures: Meaning of "Half"

LESSON CONCEPTS	LESSON	BRANCH	MODE
LESSON F. Distinguishing concave figures. "One of the figures on the screen is concave. Concave figures are caved in. Point to the box that goes with the concave figure." 3 choices, film display.	5 + 9	7/9	P
LESSON G. Counting dimes (1-9); distinguishing dimes from pennies. "Point to the box that goes with 7 dimes." 2 and 3 choices, film display.	2 + 10	8/10	P
LESSON I. Recognizing equal parts of divided figures. (Yes and no format.) "On the screen you can see a piece of paper. Does the dotted line cut the paper into two parts the same size?"	3 + 7	6/7	P
LESSON J. Recognizing figures cut in half. "Is this paper cut in half?" (Yes and no format, film display)	5 + 7	6/7	P
LESSON K. Level Drill. Addition combinations through 9. 5 levels.	0 + 10	8/10	K

BOOK 15A PURPOSE: Balancing addition equations 0-9.

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Missing addends, sums to 5. Paired equations of the type m + n = ___, m + ___ = p. First equation is held on scope until second is completed.	4 + 10	8/10 KA	5 + 8	6/8	K
LESSON B. Missing addends, m + ___ = p. Adding one and two to 4-8. (Two criteria blocks in branch. Table developed and used in first criterion block.)	2 + 10	8/10	11 + 6 0 + 6	5/6 5/6	K
LESSON C. Missing addends. ___ + p = m; p = m + ___. Paired equation format. Adding one and two to 3-5. (2 criteria blocks in branch. Table developed and used in criteria block.)	4 + 10	8/10 KA	9 + 6 0 + 6	5/6 5/6	K

BOOK 15B

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON D. Balance scale; type missing addend for sums to 9. m + n = ___, m + ___ = p.	0 + 10 0 + 10	8/10 KA 8/10 KA			K
LESSON E. Missing addends, all formats.	3 + 9	7/9 KA			K
LESSON F. Missing addends, all formats.	2 + 9	7/9			K
LESSON F brl. Build Tables; 7 with sum at right, 9 with sum at left, then mixed drill switching blanks.	8 + 8	6/8			
Lesson F br2. Missing addends. Mixed drill without table, uses combinations not given in previous tables.	0 + 6	5/6			
LESSON G. Level drill	0 + 10	8/10			K

BOOK 16 PURPOSE: Number Words - One Through Six

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON F. Written number words one and two. Count cattle on screen, choose correct number word. 2 choices, film display.	2 + 7	6/7			P
Branch: Count pictures on scope, numeral shown with number word as clue. Two choices.			8 + 6	5/6	P
LESSON G. Written number words three and four. Count animals on screen, choose number word. 2 choices. Branches: Similar task, pictures on scope.	4 + 7	6/7 KA	8 + 4 6 + 6	3/4 5/6	P
LESSON P. Level Drill. Five levels of criteria blocks. Sums to nine.	0 + 10	8/10			K
LESSON H. Game. Johnny has five pennies. Guess how many in each hand. Film display	0 + 6	5/6 KA			K
LESSON I. Number pairs having the same sum. Child completes each equation in sequence.	15 + 9	7/9 KA			K
LESSON E. Story: Pablo and Pepe in Italy. Addition with 3 addends. Equations in 2nd criteria block. Objects on film.	0 + 10 0 + 10	7/10 KA 8/10 KA			K K
LESSON J. Finding all the number pairs having the same sum. Child chooses number pairs from display, makes a table. 3 choices.	0 + 15	10/15 KA			P
LESSON K. Written number words five and six. Count horses on screen, touching box by number word. 2 choices, film display. Branches: Similar task, pictures on scope.	2 + 9	7/9	6 + 4 3 + 6	3/4 5/6	P

BOOK 17A PURPOSE: Number words - Zero Through Ten; Sums to nine With Three Addends

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Level Drill No. 11. Addition, vertical format. No. 1 Addition Combinations of 1-5. No. 2 Addition Combinations of 1-7. No. 3 Addition Combinations of 3-7. No. 4 Addition Combinations of 4-7. No. 5 Addition Combinations of 3-9. Emphasis on adding zero in all levels.	0 + 10	8/10			K
LESSON B. Story. Pablo and Pepe Count Buffalo. Learning number words for 7 and 8. "Count the buffalo and find the correct number word." 2 choices, film display.	4 + 7	6/7	6 + 4	3/4	P
Branch: No. 1 7-8 objects displayed on scope; 2 choices. No. 2 1-8 objects displayed on scope. 2 choices.			4 + 6	5/6	
LESSON C. Story. Pablo and Pepe count cattle. Learning number words for 9 and 10. "Count the steers and find the correct number word." 2 choices film display. 2 Branches:	3 + 9	7/9	6 + 4	3/4	P
No. 1-9 or 10 objects displayed on scope. 2 choices. No. 2 3-10 objects displayed on scope. 2 choices			0 + 12	10/12	
LESSON E. Level Drill No. 12 Addition, vertical format in all but No. 5. No. 1 Addition Combinations 3-6. No. 2 Addition Combinations 4-8. No. 3 Addition Combinations 4-9. No. 4 Addition Combinations 3-9. No. 5 Addition Combinations 3-9. Horizontal format, sum on left side of equal sign, blank for second addend. Emphasis in addition of zero in all levels but No. 1.	0 + 10	8/10			K
LESSON D. Pablo and Pepe count horses. Written number word for zero. "How many baby horses are there in the corral?" Find the correct number word. 2 choices, film display. Branch: objects displayed on scope with choice of two number words.	5 + 9	7/9	6 + 6	5/6	P

BOOK 17A

LESSON CONCEPTS	LESSON		BRANCH		MODE
Example: Display plane, car, ship. Question: "How many animals are there?" 2 choices.					
LESSON F. Sums with three addends, two of which are one or zero. Horizontal format. Graphic numerals.	3 + 9	7/9			K
LESSON G. Sums to 9 with three addends. Horizontal format. Graphic numerals.	4 + 12	9/12			K
LESSON H. Review of number words, one to ten. 1-10 objects displayed on scope with three choices of number words below.	0 + 12	9/12			P

BOOK 17B PURPOSE: Subtraction

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON I, J. Distinguishing dimes from pennies; learning the word dime and penny. 2 restart points. Film display. 1. "Point to the dime." 2. "Is this a dime or a penny?" (Yes, no format)	0 + 4 2 + 6	3/4 5/6			P
LESSON K. Counting dimes and pennies. "Count just the dimes on the screen. Type your answer." Film display.	2 + 6	5/6			K
LESSON L. Addition with three addends. Horizontal and vertical format. "Here's the same problem written a different way." Counting marks as clue in horizontal equation in branch.	6 + 9	7/9	0 + 6	5/6	K
LESSON M. Drill- Distinguishing concave figures. "Point to the box that goes with the figure that is concave." 3 choices, film display.	0 + 10	8/10			P
LESSON N. Story. Penny carnival. Subtracting 2 from 4-9 with pennies. 3 choices, film display.	1 + 6	5/6			P

BOOK 17B

LESSON CONCEPTS	LESSON		BRANCH	MODE
LESSON O. Story - Penny Carnival continued. Subtracting 1-5 from 2-8 with pennies. Film display.	2 + 7	6/7		K
LESSON P. Finding the equal set. Preparation for difference of sets. If criteria not met, branch child to next book. 3 choices.	1 + 9	7/9		P
LESSON Q. Difference of sets. Introducing the "take-away" sign. 2 criteria blocks. 2 and 3 choices. If criteria not met in either block, branch child to next book.	10 + 4 2 + 9	3/4 7/9		P
LESSON R. Difference of sets. Blank on left side of equal sign. If criteria not met, branch child to next book.	5 + 9	7/9		P

BOOK 18A PURPOSE: Subtraction Combinations Through Six

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Story. Jerry and his father go to the zoo. Preparation for subtraction combinations through six. "The zoo keeper has three sacks of peanuts in his wheelbarrow. He takes out one and gives it to the monkeys. How many does he have left?" Film display.	0 + 10	8/10			K
LESSON B. Subtraction with counting marks 1-6. "Here are five counting marks. We cross out two. Make believe they are taken away. How many marks are left?" Graphic numerals.	4 + 9	7/9	7 + 6	5/6	K
LESSON C. Subtraction through 6. Counting marks crossed out above numeric equation. "Use the marks to find the correct numeral to go in the blank. (graphic numerals.) No. 1 - Causing objects on scope to disappear by touching with light pen. Learning the word "invisible."	3 + 9	7/9 KA	4 + 8	6/8	K
LESSON D. Story. Pablo and Pepe in space. Story subtraction problems through 7. "Pablo and Pepe saw three very strange animals. But as soon as the animals saw them, two of them disappeared. How many were left?" film display	8 + 10	8/10 KKA			K
LESSON E. Subtraction Combinations through 6. Counting marks displayed but not crossed above numeric equations. "Put your finger over 3 marks. 6 take away 3 is how many?"	0 + 6	5/6	5 + 6	5/6	K

BOOK 18B PURPOSE: Relating Addition and Subtraction

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON L. Drill. Subtraction combinations through six. No counting marks.	0 + 9	7/9 KA	1 + 8	6/8	K
LESSON M. Story. Relating addition and subtraction. Addition equation remains on scope until following subtraction equation has been completed. Film display.	2 + 10	8/10			K
LESSON O. Subtraction combinations through 6. Vertical format.	2 + 9	7/9 KA			K
LESSON P. Subtraction and Addition sentences. Child points to + or - sign in equations on scope.	2 + 4 4 + 12	3/4 9/12 KA			P
LESSON Q. Subtraction combinations through 6. Blank on left side of the equal sign.	4 + 9	7/9 KA			K
LESSON R. Level Drill. Column addition and missing addends through 9.	0 + 10	8/10			K
LESSON S. Sums to 9. Blank on left side of equal sign.	0 + 5	4/5	0 + 8	6/8	K
LESSON T. Relating addition and subtraction. Paired equations, addition equation remains on scope until subsequent inverse subtraction equation is completed. Blank on left side of the equal sign for addition problems; on right side for subtraction.	8 + 9	7/9			K

BOOK 18C

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON F. Subtraction Combinatins, 0-6. Equation appears above counting marks. No da audio in criteria block.	6 + 9	7/9 KA			K
LESSON G. Distinguishing dimes from pennies. Choosing the row of pennies that is worth one dime. 2 choices, film display. 3 criteria blocks in lesson.	0 + 4 2 + 6 1 + 6	3/4 5/6 5/6			P
LESSON H. Dimes and Pennies. Choosing the row of coins which is worth most. (one dime, 1-14 pennies) 3 choices, film display.	0 + 10	8/10			P
LESSON I. Dimes and Pennies. Choosing the row of coins that is worth least - (one dime, 1-14 pennies). 2 criteria blocks in lesson. 2 and 3 choices, film display. Proctor call at end of first criteria block in lesson and first two criteria blocks in branch. 3 criteria blocks in branch. No. 1 distinguishing dimes from pennies. No. 2 two choices. No. 3 three choices. film display	0 + 6 3 + 4	5/6 3/4	1 + 2 2 + 4 1 + 4	2/2 KA 3/4 3/4	P
LESSON J. Subtraction combinations through 6. Counting marks displayed in tol, to2 and wa. Graphic numerals.	0 + 6	5/6			K
LESSON K. Subtraction combinations of 5 and 6. 2 criteria blocks. No. 1 Completed equations remain on scope in a table. Counting marks displayed in tol, to2 and wa. No. 2 Table remains on scope. to2 arrow shows same problem in table as aid. to3 gives answer. Graphic numerals in first criteria block.	 6 + 6 7 + 6	 5/6 5/6			K

BOOK 19A PURPOSE: Geometry - Matching Similar Figures

LESSON CONCEPTS	LESSON		BRANCH	MODE
LESSON A. Matching similar figures - same size, same position. 3 choices, film display.	5 + 9	7/9		P
LESSON B. Matching similar figures - different size, same position. 3 choices, film display.	4 + 9	7/9		P
LESSON C. Matching similar figures - same size, different position. 3 choices, film display.	4 + 9	7/9		P
LESSON D. Level Drill. Column addition and missing addends through 9.	0 + 10	8/10		K
LESSON E. Matching similar figures. Different size and position. 3 choices, film display.	4 + 9	7/9		P
LESSON F. Review. Choosing the row of pennies that is worth one dime. 3 choices, film display.	1 + 4	3/4		P
LESSON G. Dimes and Pennies. One dime + n pennies is the same as how many pennies. (through 19) 2 choices, film display.	1 + 5	4/5		P
LESSON H. Introducing the numeral ten. Choosing the correct numeral for 6-10 pennies. 3 choices, film display.	1 + 6	5/6		P
LESSON I. Child pairs equations such as "1 dime + 3 pennies" with that of "10 pennies + 3 pennies." 3 choices	1 + 6	5/6		P
LESSON J. Geometry Drill. Distinguishing squares, rectangles, triangles, circles, and line segments. 3 choices, film display.	0 + 10	8/10		P
LESSON K. Matching figures. Different size and position. 3 choices film display.	0 + 10	8/10		P
LESSON L. Introducing the cent sign. Choosing the number of cents that displayed pennies (1-10) are worth. 3 choices, film display.	1 + 6	5/6		P

BOOK 19A

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON M. Introducing numerals 11, 12 and 13, with dimes and pennies. 2 criteria blocks.					
No. 1 (ML01) Choosing the numeral that goes with displayed dimes and pennies. Screen display.	0 + 4	3/4			P
No. 2 (ML02) Pointing to numerals 11-13. 3 choices.	0 + 6	5/6			P
LESSON N. Counting dimes and pennies. "How much money is one dime and one penny?" 3 choices, film display.	0 + 4	3/4	3 + 4	3/4	P

BOOK 19B PURPOSE: Subsets

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON O: Counting money (10¢- 13¢). Display one dime and two pennies. Child chooses correct number of cents from choices on scope. 3 choices, film display. If criteria met, go to 19Q.	0 + 6	5/6			P
LESSON P. Counting money (10¢ - 13¢) Display dime and pennies mixed. Child chooses correct number of cents from answer choices on scope. 3 choices, film display. If criteria not met, branch child to next lesson, 19Q.	0 + 6	5/6			P
LESSON Q. Level Drill No. 1 z = x + __ through 5. No. 2 x + __ = z through 5. No. 3 z = x + __ through 9. No. 4 x + __ = z through 9. No. 5 __ + y = z through 9.	0 + 10	8/10			K
LESSON R. Review. Matching equal sets. 3 choices. If criteria not met, child branches to 19R.	0 + 9	7/9			P
LESSON S. Introduction to subsets. "Part of a set is called a subset. Find the subset." 3 choices. If criteria not met, branch child to 19 V.	4 + 7	5/7			P
LESSON T. Choosing the subset. 3 choices ___ ⊂ B.	0 + 4	3/4			P
If criteria not met branch child to 19R.	0 + 7	5/7			
LESSON U. Choosing the subset or the bigger set; mixed drill. ___ ⊂ B, A ⊂ ___. 3 choices. If criteria not met, branch child to 19R.	0 + 9	7/9			P
LESSON V. Introducing numerals 14 and 15 with dimes and pennies; pointing to numeral that's read. (11-15) 3 choices.	2 + 9	7/9			P
LESSON W. Counting money. Display dime and pennies on screen; object and number of cents on CRT. "Find the row that shows the correct amount of money." 3 choices,	0 + 2	2/2 KKA	1 + 6	5/6	P
film display. Branch: Dime always displayed on left.	0 + 7	6/7			

BOOK 19B

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON X. Counting pennies and dimes up to 15. Dime and pennies display on screen. Number of cents on CRT. "How much money is there?" 3 choices, film display. (Dime and pennies mixed in lesson, dime at the left in branch.)	0 + 2	2/2 KA	1 + 6	5/6	P
	0 + 6	6/7			
LESSON Y. Introducing Ordinals. Display toys on CRT. "Point to the toy you want to be first." 3 choices.	0 + 6	5/6 KKA			P
LESSON Z. Ordinals, point to the first, second and third toy. 3 choices.	3 + 7	6/7			P

BOOK 20A PURPOSE: Review

LESSON CONCEPT	LESSON		BRANCH		MODE
LESSON A. Drill. Matching similar figures, different size and position. 3 choices, film display.	0 + 10	8/10			P
LESSON B. Game. Child types number of stair steps he sees, so animal can climb them.	2 + 10	8/10 KKA			K
LESSON C. Mixed addition and subtraction problems. Child points to plus or minus sign to complete equation. Branch - mixed addition and subtraction with a + b = c; c - b = a;	0 + 9	6/9	8 + 4	3/4	
c - a = b format. 2 choices, film display.	0 + 6	5/6 KA			P
LESSON D. Choosing row of money (11 ¢ - 14¢) needed to buy object displayed on scope. 3 choices.	0 + 2	2/2	1 + 6	5/6	P
film display	0 + 7	6/7			
LESSON E. Subtraction a - b = c when a<9. Introduce word minus. Counting marks crossed out. Branch - subtraction equations with film display - red and blue balls.	6 + 9	7/9 KA	5 + 6	5/6	K
LESSON F. Drill. Matching similar figures - different size and position. 3 choices, film display.	0 + 10	8/10			P

BOOK 20B PURPOSE: Subtraction II $c - a = b$ where $7 < c < 9$

LESSON CONCEPT	LESSON		BRANCH		MODE
LESSON G. $c - a = b$; c marks given; none crossed out. Branch: relation between addition and subtraction, marks as clues. Same three criteria blocks as A. except marks as clues.	4 + 9	7/9 KA	5 + 8	6/8	K
LESSON I. Subtraction. No marks. Branch: Making and using table of subtraction problems.	4 + 9	7/9	12 + 8 0 + 8	6/8 KA 6/8 KA	K
LESSON J. Story. Stephen at grocery store. Addition and subtraction equations. Film display.	1 + 6	5/6 KA			K
LESSON K. Level drill $c = \underline{a} + b$ first four levels; position of blank varies in fifth level.	0 + 10	8/10			K
LESSON L. Column subtraction	4 + 9	7/9 KA			K
LESSON M. Drill Geometry. Counting sides of figures. Film display	1 + 9	7/9			K
LESSON N. Subtraction. Blank on left side of equal sign. 3 choices.	4 + 9	7/9 KA			P
LESSON O. Subtraction as inverse of addition. Child completes 9 addition equations of this form: $c = a + \_\_$ with pictures, then does $c - a = \_\_$. film display.	9 + 9	7/9 KA			K

BOOK 21 A PURPOSE: Counting and Typing to 19

LESSON CONCEPTS	LESSON		BRANCH	MODE
LESSON A. One dime + three pennies equals ten pennies + three pennies. 3 choices.	0 + 10	8/10		P
LESSON B. Matching similar figures: different size and position. 3 choices, film display.	0 + 10	8/10		P
LESSON C. Learning numerals 13-19. "Which row of money has sixteen cents? (display one dime and n pennies. 3 choices, film display.)	4 + 9	7/9		P
LESSON D. Pointing to numeral that's read. (16-19) 3 choices.	0 + 8	6/8		P
LESSON E. Counting 10 + n objects. "Here are ten ducks. Here are some more ducks. How many all together?"(16-19 - 3 choices). If criteria met in first criteria block, skip to Lesson F.	0 + 4 0 + 4	4/4 3/4		P
LESSON F. Story - setting the table. "There are two plates. How many more plates does Sara need?" 4 choices.	0 + 6	5/6 KA		P
LESSON G. Find the number that comes after. (13-19)	0 + 9	7/9		P
LESSON H. Geometry - "Which region is cut in half?" 2 choices, film display.	0 + 10	8/10		P
LESSON I. Typing numerals 10-19 (If criteria not met on first criteria block, P.C. Otherwise continue.)	0 + 3 0 + 7	2/3 6/7		K
LESSON J. Game - helping the steam shovel fill in holes in the road. Type missing numeral in number sequence.	0 + 10	8/10		K
LESSON K. Distinguishing geometric figures. Circle, square, triangle, line segment. 3 choices, film display.	0 + 10	8/10		P

BOOK 21B PURPOSE: Place Value

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON L. Place Value - count-10 + n loaves of bread. "The bread man always carries ten loaves in his case and some in his hand. How many does he have now?" (11-19) If criteria not met in first block, P.C. Otherwise continue.	0 + 4 0 + 5	3/4 4/5			K
LESSON M. Game "Type the right answers to these subtraction problems to make the kite go as high as the bird."	No criteria - everyone wins.				K
LESSON N. Story - The money tree. Counting dimes and pennies and typing the number of cents. Film display.	0 + 9	7/9			K
LESSON O. Typing number of cents displayed on film. (dimes and pennies).	0 + 9	7/9			K
LESSON P. Geometry - Finding the missing piece to fit in the puzzle. Film display, 3 choices.	0 + 7	6/7 KA			P
LESSON Q. Addition - 10 + n to 19. (Film display of dime + n pennies for tol and wa.) Branch: Same problems with pictures from breadman story. If criteria not met in first block, P.C. Otherwise continue.	0 + 9	7/9	1 + 3 1 + 6	2/3 5/6	K

BOOK 22 A PURPOSE: Addition on the Number Line

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Game - Making the ship move by touching numerals in sequence. (0-8)	0 + 8	6/8 KA			P
LESSON B. Typing the "number that comes after" to twelve. (one numeral displayed)	2 + 7	6/7			K
LESSON C. Filling in the missing numeral on the number line.	5 + 9	7/9			K
LESSON D. Showing addition equations on the number line. Sums to twelve. "The first loop goes over six spaces. The second loop goes over four more spaces. Which number sentence is shown on the number line?" 3 choices.	1 + 9	7/9	2 + 4 1 + 8	3/4 6/8	P
LESSON E. Level Drill Addition.	0 + 10	8/10			K
LESSON F. Typing the answer to the number sentence shown on the number line. (Both loops shown.) Sums to twelve.	3 + 12	9/12	3 + 9	7/9	K
LESSON G. Story. Pablo and Pepe in Hawaii. Number words to ten. 3 choices, film display.	0 + 10	8/10			P

BOOK 22B PURPOSE: Addition on the Number Line - Counting by Two's

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON H. Game - Rhymes - "How many animals were left?"			No criteria		P
LESSON I. Sums to twelve on the number line. (Second loop not shown.)	1 + 5 0 + 9	4/5 7/9	2 + 8	6/8	K
LESSON J. Geometry - Distinguishing geometric figures. 3 choices, film display.	0 + 10	8/10			P
LESSON K. Sums to twelve on the number line. First loop; shown only in tol and wa.	4 + 9	7/9	2 + 9	7/9	K
LESSON L. Story - Pablo and Pepe underwater. (Sums to nine.) film display	0 + 10	8/10 KKA			K
LESSON M. Addition - sums to thirteen. Number line shown for tol and wa. Branch - Child builds tables. Empty number line for tol and wa.	0 + 12	9/12	10 + 11	8/11	K
LESSON N. Introduction to counting by two's. Counting shoes and boots.	4 + 9	7/9			K

BOOK 22C

LESSON P. Counting by two on the number line. Typing the missing numeral in sequence by two's.	2 + 8	6/8			K
LESSON Q. Making a table of addition problems a + a = c where c < 13.	6 + 5	4/5 KA			K
LESSON R. Typing the missing numeral in sequence by two's on the number line to eighteen.	2 + 7	6/7			K
LESSON S. Addition - n + 1 to 13.	3 + 6	5/6			K

BOOK 23A PURPOSE: Counting by Ten's

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Story problems - sums to 12. Equation shown.	0 + 6	5/6 KA			K
LESSON B. Pointing to multiples of 10 on the scope. (Number line display on film) 3 choices.	2 + 7	6/7 KKA			P
LESSON C. Choosing the missing numeral in number line sequence by 10's to 100. 3 choices.	0 + 9	7/9 KA			P
LESSON D. Geometry - distinguishing geometric figures. 3 choices.	0 + 10	8/10			P
LESSON E. Choosing the sentence shown on the number line. (Sums to 12.) 3 choices.	0 + 7	6/7	0 + 8	6/8	P
LESSON F. Counting with dimes in ten's. Choosing the amount of cents displayed. 3 choices, film display.	0 + 9	7/9			P
LESSON G. Level Drill	0 + 10	8/10			K

BOOK 23B PURPOSE: Counting by Ten's

LESSON CONCEPTS	LESSON	BRANCH	MODE
LESSON H. Choosing the number sentence shown on the number line. 3 choices.	0 + 9	7/9	P
LESSON I. Typing multiples of ten to 100.	0 + 4 0 + 5	3/4 KA 4/5 KA	K
LESSON J. Sums to 12 on the number line - both loops shown.	5 + 10	8/10	K
LESSON K. Sums to 12 on the number line. Second loop unfinished.	5 + 10	8/10	K
LESSON L. Typing the missing numeral in sequence by ten's on the number line. Film display.	1 + 9	7/9	K
LESSON M. Geometry - Story - Cutting pieces of paper in half. "Is the paper cut in half?" (Yes/no format, film display)	1 + 10	8/10 KKA	P
LESSON N. Typing the missing numeral in number line sequence by 10's.	0 + 9	7/9	K
LESSON P. Typing multiples of ten. n dimes displayed on film. "How much are the dimes worth?"	1 + 9	7/9 KKA	K

BOOK 24A PURPOSE: Counting by Five's

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Drill - Counting by two's. Typing missing numeral in sequence by two's. 2-4 numerals displayed.	0 + 10	8/10			K
LESSON B. Drill - Addition a + b = c where c < 15.	0 + 6	5/6			K
LESSON C. Distinguishing nickels. Film display, 3 choices.	1 + 4	3/4			P
LESSON D. Pointing to the coin worth five cents. Film display, 3 choices.	0 + 7	6/7			P
LESSON E. Addition combinations of 11 and 12. Empty number line displayed.	4 + 10	8/10	0 + 11	8/11	K
LESSON F. Pointing to the row of pennies worth a nickel or a dime. Film display	0 + 5	4/5			P
LESSON H. Pointing to the row of nickels worth 10, 15, 20 cents. 3 choices.	0 + 2 0 + 2 0 + 2 0 + 5	2/2 KKA 2/2 KKA 2/2 ← KKA 4/5			P
LESSON I. Reading 10, 15, 20 cents displayed on scope and pointing to appropriate row of nickels. 3 choices, film display.	0 + 7	6/7			P
LESSON J. Addition combinations of 10, 11 and 12. Empty number line as clue in tol and wa.	3 + 12	9/12	3 + 8	6/8	K

BOOK 24B PURPOSE: Counting by Five's.

LESSON CONCEPTS	LESSON		BRANCH	MODE
LESSON K. Addition. a + a = c where c < 15. Child makes table.	4 + 5	4/5		K
LESSON L. Typing the number that comes before. Three to one numerals displayed.	2 + 5	4/5		P
LESSON M. Pointing to multiples of 5 to 50. Film display of number line in sequence by five's. 3 choices.	2 + 5	4/5		P
LESSON N. Choose the missing numeral in number line sequence by five's.	0 + 5	4/5		P
LESSON P. Counting by five's with nickels. Film display. 3 choices.	1 + 5	4/5 KKA		P
LESSON Q. Geometry. Find the matching figure. 3 choices, film display.	0 + 10	8/10		P
LESSON R. Typing numerals 25, 35, 45. First criteria block - child types numeral displayed. Second - child types numeral that's read.	0 + 3 0 + 7	2/3 KKA 6/7 KA		K
LESSON S. Pablo and Pepe in Africa. Story addition problems. Sums to 13. "You can see 3 monkeys, but there are 3 more you can't see. How many are there all together?" Film display.	0 + 7	6/7 KKA		K
LESSON T. Typing the missing numeral on the number line sequence by five's.	0 + 9	7/9		K
LESSON V. Bingo Game - Sums with three addends. No criteria in 2nd block.	1 + 5	4/5 KKA	2nd block no criteria	K
LESSON U. Typing the missing numeral in sequence by five's.	0 + 9	7/9		K
LESSON W. Typing the number of cents in n nickels to 50 cents. Film display.	0 + 10	8/10 KKA		K

BOOK 25A PURPOSE: Addition Combinations 13 - 15

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON A. Addition combinations of 13, 14, 15. a and b marks displayed.	3 + 12	8/12			K
LESSON B. Addition combinations of 13, 14, 15 - Marks in tol and wa. Branch - film display showing child how to use fingers.	3 + 12	9/12	3 + 12	8/12	K
LESSON C. a + b = c + d. "Six plus one is seven. What other two numbers can you put together to get seven?" 3 choices.	5 + 6	4/6			P
LESSON D. Geometry - Child touches numbered dots in sequence to copy displayed figure.	1 + 7	5/7 KKA			P
LESSON E. Level Drill 1) a + b = ___, c < 10 2) a + b = ___, ___ = a + b 3) a - b = ___, c < 6 4) c - b = ___, c < 10 5) c - b = ___, c < 10	Level 1-3 Level 4-5	12/15 KKA 12/15 KA			K
LESSON F. Addition combinations of 13-15, vertical format.	3 + 12	8/12			K

BOOK 25B PURPOSE: Addition Combinations 10-15 - Switching Blanks

LESSON CONCEPTS	LESSON		BRANCH		MODE
LESSON H. Story problems with paired equations. a + b = ___ a + ___ = c	0 + 7 (14 responses)	5/7			K
LESSON I. Addition combinations missing addends, 11-15 - a + ___ = c. Three criteria blocks each with a table of 5 problems for reference.	0 + 5 0 + 5 0 + 5	3/5 3/5 3/5			K
LESSON J. Game introducing variables. "Which number's underneath the hand in this equation?" (a + hand = c . sums of 10-15).	3 + 9	6/9			K
LESSON K. Addition combinations, missing addends, 12-15. a + ___ = c.	0 + 9	6/9			K
LESSON L. Geometry - copy the figure. Two dots numbered.	0 + 11	8/11			P
LESSON M. Sums 10-15 - paired equations. a + b = ___ ___ + b = c. Branch - 3 tables on film.	4 + 9 (22 responses)	6/9	2 + 12	8/12	K
LESSON N. Hand game - hand + b = c. "Which number's underneath the hand?" Sums of 10-15.	0 + 9	6/9			K
LESSON PL. "What time does the clock say?" 3 choices.	0 + 10	8/10			P
LESSON QL. Sums 10-15 ___ + b = c.	0 + 9	6/9			K

Appendix 2

Main Data Analysis Program for Mathematics and Reading Curricula at Brentwood

NAME	PURPOSE
COPY2:	To copy files of constant-length records from one magnetic-tape unit onto the other.
CSATS:	To calculate correlation coefficient, T-test values and related computations.
CTTD:	To transfer a file of 17-word records from tape-unit 1 to disk-unit 2.
DAPM2:	To produce two item-analysis reports containing response raw data totals, mean latencies, percentages and latency variances.
DAPM4:	To produce the Mathematics Lesson-Percentage Tape.
DAPM5:	To analyze response data by concept and build a tape one file/student for each book of math data.
DAPM7:	To produce mathematics weekly reports.
DAPM8:	To produce the Mathematics Lesson-Correct Latency Tape.
DAPR1:	To determine restart run number and cell number for reading student responses.
DAPR2:	To produce a reading report from a 16-word PHILLIP tape of one problem tape in one lesson--one report for each cell under each restart run number.
DAPR3:	To produce the reading daily report.
DAPR4:	To produce a reading report(s) from a 16-word PHILLIP tape of a binary-choice game in a lesson--one report for each student under each restart run number.
LBEST:	To find the "best fitting" straight line for a set of data.
LIST:	To list a deck of cards on the printer--25 cards (lines) per page with double spacing.
MAMP:	To produce Math Audio Manuscripts and Math Manuscript Tapes or to produce only Math Manuscript Tapes.
MARM:	To produce the Math Audio Recorders Manuscript.
MLIST:	To print an Audio Manuscript from a MAMP output tape.
MLR1:	To perform multiple linear regression analysis.
PBEST:	To find the "best fitting" straight line and plot a scatter diagram for a set of data.

NAME	PURPOSE
PHILR:	To read a PHILLIP, 16-word record, tape and list it on the printer--50 records (lines) per page.
PTDDR:	To delete duplicate Student Number - E.P. Identifier records from a standard 17-word Student Performance Tape.
SLSUM:	To prepare a data report in student number-response identifier (lesson)--data sequence.
SØRT2:	To sort and strip math daily response tapes by student number.
SØRT3:	To sort and strip reading daily response tapes by student number.
SØRT4:	To sort Math Female Tapes by student number.
SØRT5:	To sort Reading Female Tapes by student number.
STRP1:	To strip subsets of responses from a compressed data tape.
STRP2:	To strip subsets of responses from a Female Named Tape.
TAPE:	To perform magnetic tape handling functions from the 1816 keyboard.
TBLAC:	To produce series A and C reports for the mathematics group.
TBLB:	To produce series B reports for the mathematics group.
TBLE:	To produce Table E report for the mathematics group.
TBLG:	To produce the series G reports for the mathematics group.
TTPB:	To list a 17-word format tape.
BKS01:	To backspace tape on Unit 0 one record.
BKS11:	To backspace tape on Unit 1 one record.
CNAME:	To convert mathematical concept ordinals into EBCD concept names.
CØRR1 and CØRR2:	To compute means, standard deviations, sums of cross-products of deviations, and correlation coefficients.
DATAO:	To read the compressed-daily-tapes tape.
DTC:	To transfer a record from a disk unit (presently disk-unit 2).
GMARK:	To calibrate the axes for an on-line printer plot's grid.
IPLOT:	To initiate an on-line printer plot.
LOC and LOK:	To reference elements within a matrix stored in vector fashion.
MRG:	To merge tape and disk records onto a tape.

NAME	PURPOSE
MTERR:	To type an error message for assembly routines.
MTWR:	To write a tape record (maximum length 100 words) in anti-FORTRAN order from a buffer in FORTRAN order.
NXTC:	To transfer characters from a mathematics Manuscript Tape to the calling program.
PLØT:	To plot a point on an on-line printer plot.
PRØLP:	To print an on-line plot.
REDK:	To record one sector from a specified disk unit and store in FORTRAN order in a specified buffer.
SDEOF:	To search for a double EOF and backspace over the last EOF.
SIDU:	To convert one lower-case EBCDIC word (2 characters) to one upper-case EBCDIC word (2 characters).
SINRW:	To initiate a rewind of a tape and return control to the user without testing for completion of operation.
SMTRD:	To read a variable length magnetic-tape record into core and check for EØF.
SNAME:	To convert student number into student name.
TCPY:	To copy one file of constant-length records from one magnetic-tape unit onto the other.
TTD:	To store any file of tape records (maximum length 100 words) on a disk pack.
UNLDO:	To rewind and unload tape on Unit 0.
UNLD1:	To rewind and unload tape on Unit 1.
WRDK:	To write one disk sector from a specified 320-word array stored in FORTRAN order.
XGRID:	To set the horizontal scaling for an on-line printer plot.
YGRID:	To set the vertical scaling for an on-line printer plot.
CFCTR:	To compute the criterion factor from the mathematics lesson number or mathematical concept ordinal.
F1:	To compute the probability transformation for proportion of correct data.
IBLK:	To convert mathematics lesson number (first four characters of EPID) to block number.
ICØMP and JCOMP:	To determine if one number is close to another.
ISORD:	To label each of up to 120 different student numbers with a unique ordinal number.

NAME	PURPOSE
JMPS and JMPSW:	To test sense switches.
KDAYF:	To convert the date field (calendar date) in the MATHEMATICS RESPONSE TAPE records into a day ordinal.
KUCLC:	To convert one upper-case EBCDIC word (2 characters) to one lower-case EBCDIC word (2 characters).
LASTK:	To map a mathematics block number to the block number of its concept predecessor.
LSTUN:	To convert mathematics student numbers into student ordinals.
L2CØN:	To convert mathematics lesson numbers into mathematical concept ordinals.
MAGTP:	To read a record of a magnetic tape without using a format statement.
MAGTR:	To read a record of a magnetic tape without using a format statement and store it in anti-FORTRAN order.
MØVLF:	To shift any word n bits to the left.
MOVRF:	To shift any word n bits to the right.
NCELL:	To compute Present Cell Number.

Appendix 3

Publications and Lectures

Publications

Richard C. Atkinson

A test of three models for stimulus compounding with children. *Journal of Experimental Psychology*, 1964, *67*, 52-58 (with R. C. Calfee, G. R. Sommer, and W. E. Jeffrey).

Short-term memory with young children. *Psychonomic Science*, 1964, *1*, 255-256 (with D. N. Hansen and H. A. Bernbach).

A comparison of paired-associate learning models having different acquisition and retention axioms. *Journal of Mathematical Psychology*, 1964, *1*, 285-315 (with E. J. Crothers).

Paired-associate models and the effects of list length. *Journal of Mathematical Psychology*, 1965, *2*, 254-265 (with R. C. Calfee).

Models for optimizing the learning process. *Psychological Bulletin*, 1966, *66*, 309-320 (with G. J. Groen).

Computer-assisted instruction in initial reading: The Stanford Project. *Reading Research Quarterly*, 1966, *2*, 5-25 (with D. N. Hansen).

Mathematical models for memory and learning. Technical Report 79, September 20, 1965, Institute for Mathematical Studies in the Social Sciences, Stanford University (with R. M. Shiffrin).

Reading instruction under computer control. *American School Board Journal*, 1967, *155*, 16-17.

Learning aspects of computer-assisted instruction. In R. W. Gerard (Ed.), *Computers and Education*. New York: McGraw-Hill, 1967. Pp. 11-63.

Instruction in initial reading under computer control: The Stanford Project. *Journal of Educational Data Processing*, 1967, *4*, 175-192.

Computer-based instruction in initial reading: A progress report on the Stanford Project. Technical Report 119, August 25, 1967, Institute for Mathematical Studies in the Social Sciences, Stanford University (with H. A. Wilson).

Patrick Suppes

Problems of optimization in learning a list of simple items. In M. W. Shelly, II, and G. L. Bryan (Eds.), Human Judgments and Optimality. New York: Wiley, 1964. Pp. 116-126.

Computer-based mathematics instruction. Bulletin of the International Study Group for Mathematics Learning, 1965, 3, 7-22.

Towards a behavioral foundation of mathematical proofs. In K. Ajdukiewicz (Ed.), The Foundations of Statements and Decisions: Proceedings of the International Colloquium on Methodology of Science, September 18-23, 1961. Warszawa: PWN - Polish Scientific Publishers, 1965. Pp. 327-341.

On the behavioral foundations of mathematical concepts. Monographs of the Society for Research in Child Development, 1965, 30, 60-96.

Learning the new mathematics. New Directions in Mathematics, Membership Service Bulletin 16-A, Association for Childhood Education International, 1965. Pp. 57-64.

The kinematics and dynamics of concept formation. Proceedings for the 1964 International Congress for Logic, Methodology and Philosophy of Science. Amsterdam, Holland: North-Holland, 1965. Pp. 405-414.

Experimental teaching of mathematical logic in the elementary school. The Arithmetic Teacher, March 1965, 187-195. (with Frederick Binford)

Accelerated program in elementary-school mathematics--the first year. Psychology in the Schools, 1965, 2, 195-203. (with D. Hansen)

Observable changes of hypotheses under positive reinforcement. Science, 1965, 148, 661-662. (with M. Schlag-Rey)

Latencies on last error in paired-associate learning. Psychonomic Science, 1965, 2, 15-16. (with M. Schlag-Rey and G. Groen)

Mathematical concept formation in children. American Psychologist, 1966, 21, 139-150.

Tomorrow's education. Education Age, 1966, 2, 4-11.

Towards a behavioral psychology of mathematical thinking. In J. Bruner (Ed.), Learning about Learning (a Conference Report). Washington: U. S. Government Printing Office, 1966. Pp. 226-234.

The psychology of arithmetic. In J. Bruner (Ed.), Learning about Learning (a Conference Report). Washington: U. S. Government Printing Office, 1966. Pp. 235-242.

Accelerated program in elementary-school mathematics--the second year. Psychology in the Schools, 1966, 3, 294-307.

The axiomatic method in high-school mathematics. The Role of Axiomatics and Problem Solving in Mathematics. The Conference Board of the Mathematical Sciences, Washington, D. C.: Ginn, 1966. Pp. 69-76.

Plug-in instruction. Saturday Review, July 1966, pp. 25, 29, 30.

The uses of computers in education. Scientific American, September 1966, 206-221. Reprinted in Information, A Scientific American Book. San Francisco: W. H. Freeman, 1966. Pp. 157-174. (German translation Anwendungen elektronischer Rechenanlagen in Unterricht. In Information Computer und künstliche intelligenz. Frankfurt am Main: Umschau Verlag, 1967. Pp. 157-172.)

Some models for response latency in paired-associates learning. Journal of Mathematical Psychology, 1966, 3, 99-128. (with G. Groen and M. Schlag-Rey)

Arithmetic drills and review on a computer-based teletype. Arithmetic Teacher, April 1966, 303-309. (with M. Jerman and G. Groen)

On using computers to individualize instruction. In D. D. Bushnell and D. W. Allen (Eds.), The Computer in American Education. New York: Wiley, 1967. Pp. 11-24.

The psychological foundations of mathematics. Les Modèles et la Formalisation du Comportement. Colloques Internationaux du Centre National de la Recherche Scientifique. Editions du Centre National de la Recherche Scientifique. Paris: 1967. Pp. 213-242.

Applications of mathematical models of learning in education. In H. O. A. Wold (Scientific Organizer), Model Building in the Human Sciences. Entretiens de Monaco en Sciences Humaines, Session 1964. Monaco: Union Europienne D'Editions, 1967. Pp. 39-49.

The case for information-oriented (basic) research in mathematics education. In J. M. Scandura (Ed.), Research in Mathematics Education. Washington, D. C.: NCTM, 1967. Pp 1-5. (with G. Groen)

Some counting models for first-grade performance data on simple addition facts. In J. M. Scandura (Ed.), Research in Mathematics Education. Washington, D. C.: NCTM, 1967. Pp. 35-43. (with G. Groen)

Lectures

Karl Anselm

Computer-assisted instruction and the media specialist. Presented at the National Education Defense Act Media Institute, State University of New York, College at Brockport, July 3, 5, 1967.

Computer-assisted instruction and the Stanford-Brentwood CAI reading project. Presented at the National Defense Education Act Reading Institute, State University of New York, College at Brockport, July 6, 1967.

Educational innovation. Presented at the McComb Institute, Stanford University, July 17, 1967.

The Stanford-Brentwood CAI project. Presented at the Institute for Mathematical Studies in the Social Sciences Reading Institute, Stanford University, July 24, July 31, August 7, and August 14, 1967.

Computer-assisted instruction and the classroom teacher. Seminar presented at the Experienced Fellowship Program, Stanford University, August 1, 1967.

Look, look. See CAI. A.R.E., Classroom Teachers Committee of Richmond, California, February 1, 1968.

Computer control...Does not compute. New Educational Technologies Higher Education Seminar, United States Student Press Association. Presented at Villa Hotel, San Mateo, California, February 23, 1968.

What to do until the computers arrive. February 24, 1968.

Read the signs: The school of the future is here today. (Telelecture via telephone) Educational Media Specialist Institute, University of Colorado, Boulder, Colorado, March 9, 1968.

Richard C. Atkinson

Colloquium at University of California, Los Angeles, Department of Psychology: Optimizing the learning process: a theory of instruction, April 29, 1965.

Mathematical models for learning and perception. Ames Research Center, Moffett Field, California, June 24, 1965.

A theory of instruction. Social Science Research Council Conference on Learning and the Educational Process, June 30, 1965.

Learning theory and computer-based instruction. San Diego State College, Department of Psychology, July 15, 1965.

Future developments in mathematical applications in the social sciences. McGraw-Hill Publishing Company Yearly Meeting, Berkeley, California, August 26, 1965.

Learning theory and computer-based instruction. Invited talk at the American Psychological Association Convention, Chicago, Illinois, September 3, 1965.

Mathematical models for memory and learning. Invited talk at the Third Conference on Learning, Remembering and Forgetting, Princeton, New Jersey, October 5, 1965.

CAI learning aspects. Invited talk at the Conference on Computers and Universities, University of California, Irvine, California, November 9, 1965.

Invited talk at the Conference on Mathematical Theories of Perception, Puerto Rico, November 26, 1965.

CAI instruction. Invited talk at the American Educational Research Association Convention, Chicago, Illinois, February 17, 1966.

Seminar on Discrimination and Learning Theory at the Center for the Advanced Study in the Behavioral Sciences, Stanford, California, June 20 - July 30, 1966.

EDUCOM Taskforce Network Meetings, Boulder, Colorado, July 5, 1966.

APA Convention, Psychometric Society Convention, New York, September 2-6, 1966.

Foothill College Faculty Retreat, Asilomar, California, January 6-8, 1967.

International Reading Association Convention, Seattle, Washington, May 4-6, 1967.

Course on Perception and Learning, University of California, Los Angeles, California, June 5-10, 1967.

Medical center of the 21st century. Seminar given at the Edith Meyers Auditorium of the Children's Hospital Medical Center, Oakland, California, October 6, 1967.

International Book Fair, Frankfurt, Germany, October 11-25, 1967.

Computerized instruction and the learning process. Invited talk at the Educational Testing Service Meetings, New York City, New York, October 28, 1967.

CAI: theory and applications. Invited talk at the University of Chicago, School of Education, Chicago, Illinois, October 30, 1967.

Some two process models for learning and memory. Invited talk at the University of Chicago Colloquium, Mathematical Biology Group, Chicago, Illinois, October 31, 1967.

Teaching children to read under computer control. Seminar in Bio-Behavioral Sciences, Stanford Medical Center, Stanford, California, November 14, 1967.

What makes Johnny learn. CACER Annual Conference on Education Research, San Diego, California, November 15-16, 1967.

Jamesine E. Friend

Addition and subtraction via computer-assisted instruction. Presented at the Joint Meeting of the Oregon Council of Teachers of Mathematics and the Northern Section of the California Mathematics Council, Weed, California, October 7, 1967.

The Stanford-Brentwood Project. Presented at the November meeting of the Scientific Research Society of America, Sequoia Branch, Palo Alto, California, November 30, 1967.

Addition and subtraction via computer-assisted instruction. Presented at the Fall Conference of the California Mathematics Council, Northern Section, Asilomar, California, December 8, 1967.

Max Jerman

Computer-assisted instruction in arithmetic. Presented at the Annual Meeting of the Idaho State Teachers of Mathematics, Boise, Idaho, October 12, 1967.

Using the computer for research in education. Presented at the Annual Meeting of the Idaho State Teachers of Mathematics, Boise, Idaho, October 13, 1967.

Computer-assisted instruction, the Stanford project. Lecture and demonstration at the Annual Meeting of the National Science Teachers, Claremont Hotel, Berkeley, California, October 26-27, 1967.

The uses of time-sharing systems. Presentation as a panel member at the annual meeting of COMMON, Sheraton-Palace Hotel, San Francisco, California, December 12, 1967.

(1) Computer-assisted instruction, the drill and program. (2) Review of research in programmed instruction. (3) Preparing objectives for programmed instruction. (4) Preparing objectives for programmed instruction. Lectures presented at the McComb Institute, Stanford University, Stanford, California, July 17-20, 1967.

Workshop in Computer-Assisted Instruction conducted at Morehead State University, Morehead, Kentucky, February 1-3, 1968.

Computer frontiers in teaching. Two lectures presented at the Individualized Instruction Conference, Cabrillo College, Aptos, California, March 23, 1968.

Patrick Suppes

Kinematics and dynamics of concept formation. International Congress for Logic, Methodology and Philosophy of Science, Hebrew University, Jerusalem, Israel, August 31, 1964.

Behavioral foundations of mathematics. Department of Mathematics Colloquium, University of Illinois, Urbana, Illinois, October 2, 1964.

Quantifying human behavior. Department of Philosophy Colloquium, University of Illinois, Urbana, Illinois, October 2, 1964.

Survey of mathematical learning theory. Department of Mathematics, University of Illinois, Urbana, Illinois, October 2, 1964.

Logical inference and mathematical structure at the elementary-school level. Annual Meeting of the Illinois Council of Teachers of Mathematics, Urbana, Illinois, October 3, 1964.

Probability learning of rats in continuous-time experiments. Fifth Annual Scientific Meeting, The Psychonomic Society, Inc., Ontario, Canada (with E. Karsh), October 9, 1964.

Workshop on Modern Mathematics for Primary-Grade Teachers, Toronto School Board, Canada, October 30, 1964.

Computer-based instruction in the elementary school. IBM, Los Gatos, California, November 5, 1964.

The mathematical mind of the elementary-school child. National Council of Teachers of Mathematics, Atlanta, Georgia, November 20, 1964.

How can learning theory contribute to mathematics education? General Session, California Mathematics Council, Northern Section, Monterey, California, December 12, 1964.

Computer-based laboratory for teaching elementary-school mathematics. California Mathematics Council, Northern Section, Monterey, California, December 12, 1964.

A survey of mathematical learning theory. Invited Address, American Statistical Association, Chicago, Illinois, December 28, 1964.

Participant, Seminar on Geometry in the Kindergarten and the Pre-Kindergarten Mathematics Curriculum, Board of Education, New York City, New York, January 25, 1965.

Mathematical concept formation in children (seminar). Educational Testing Service, Princeton, New Jersey, February 1, 1965.

Computer-based instruction: the next revolution in education (lecture). Educational Testing Service, Princeton, New Jersey, February 2, 1965.

The implication for testing of computer-based instruction (seminar). Educational Testing Service, Princeton, New Jersey, February 4, 1965.

New directions in the elementary-school mathematics curriculum (seminar). Educational Testing Service, Princeton, New Jersey, February 5, 1965. (The four lectures listed for ETS, February 1 to 5, were given in connection with invitation by ETS as Distinguished Visiting Scholar.)

Intuition and logical inference in elementary-school mathematics. Invited address, National Council of Teachers of Mathematics, Detroit, Michigan, April 24, 1965.

Computer-assisted instruction in the schools: prospects, potentialities, problems. IBM, Symposium, Westchester Country Club, New York, May 3, 1965.

Computer-based laboratory for learning and teaching. Distaff Club, Stanford University, Stanford, California, May 12, 1965.

A computer-based laboratory for learning. Department of Psychology, Indiana University, Bloomington, Indiana, May 26, 1965.

Language learning. Symposium Chairman, Western Psychological Association, Honolulu, Hawaii, June 17, 1965.

The psychological foundations of mathematics. Le Centre National de la Recherche Scientifique, Paris, France, July 11, 1965.

Information processing and choice behavior. Symposium on Mathematical Methods in the Social Sciences, International Colloquium for Philosophy of Science, Bedford College, London, England (with Duncan Luce), July 15, 1965.

Computer-based instruction in elementary-school mathematics. Shell Merit Program, Stanford University, Stanford, California, July 22, 1965.

Some remarks on computer-based instruction in the elementary school. National Academy of Education at Carnegie Endowment for International Peace Building, New York, September 16-17, 1965.

Teaching elementary-school modern mathematics in grade 1. Dallas Independent School District, Dallas, Texas, September 27, 1965.

Teaching modern mathematics in grade 2. Dallas Independent School District, Dallas, Texas, September 28-29, 1965.

Teaching elementary-school modern mathematics in grade 1. Dallas Independent School District, Dallas, Texas, September 30, 1965.

Progress in computer-based instruction. Psychology Department Seminar, University of Texas, Dallas, Texas, September 30, 1965.

Individualized instruction. Center for Advanced Study in the Behavioral Sciences, Stanford University, Stanford, California, October 30-31, 1965.

On using computers to individualize instruction. Conference (sponsored by Brooks Foundation, Santa Barbara) held at Rickey's, Palo Alto, California, November 1, 1965.

Intuitive geometry in the elementary school. Informal Conference, Stanford University, Stanford, California, November 20, 1965.

Mathematical theories of perception. Conference sponsored by Mathematical Social Science Board through the Center for Advanced Study in the Behavioral Sciences at Stanford, held in Puerto Rico, November 25-28, 1965.

Sets and geometry in the primary grades. Darien Public Schools, Darien, Connecticut, (Phone hookup), December 7, 1965.

Programs in new mathematics for the elementary school. Public Lecture, Cornell University, Ithaca, New York, January 13, 1966.

(1) Computer-assisted mathematics instruction in the schools, (2) Mathematical mind of the elementary-school child, (3) Geometric concepts in the junior-high school. Alamo District Council of Teachers of Mathematics, National Council of Teachers of Mathematics, Trinity University, San Antonio, Texas, February 4-5, 1966.

The use of computers in instruction. Association for Computing Machinery, Sunnyvale, California, February 17, 1966.

Using computers to teach elementary-school mathematics. 1966 Regional Meeting, National Council of Teachers of Mathematics, Washington, D.C., March 5, 1966.

Teaching children with computers. Santa Clara Valley Mathematics Association, April 22, 1966.

Tomorrow's education. Summer University of Finland, Vasa, Finland, (3 lectures), June 27-29, 1966.

On learning the new mathematics. Radio phone hookup, San Francisco, August 18, 1966.

Electronic individualization of instruction. Pre-School Workshop for School Administrators in the Greater San Diego Area, San Diego, California, August 24, 1966.

Logical and mathematical concept formation in children. Symposium on cognitive development in children, American Psychological Association, New York, September 4, 1966.

Report on Stanford-Brentwood CAI Laboratory. California State Board of Education, Los Angeles, California, September 8, 1966.

CAI in elementary-school mathematics. Institute of Human Learning Graduate School, Florida State University, Tallahassee, Florida, September 18, 1966.

CAI teaching techniques and equipment. The Institute of Electrical and Electronics Engineers, Stanford, California, September 27, 1966.

The Stanford Project. Conference on Coordination of Curriculum Studies, sponsored by USOE and NSF, Chicago, Illinois, October 14, 1966.

Concept learning. Discussant, Symposium on research approaches to the learning of school subjects, sponsored by Phi Delta Kappa and School of Education, University of California, Berkeley, California, October 28, 1966.

The promise of the computer. TV Symposium, KQED, Channel 9, San Francisco (one-hour panel shown in conjunction with the Fall Joint Computer Conference), November 7, 1966.

Prospects for computers in education. Fall Joint Computer Conference, San Francisco, California, November 8, 1966.

Computers and children. Fall Joint Computer Conference, San Francisco, California, November 9, 1966.

Impact of technology in the elementary school. Elementary Principals' Association, Southern Nevada Vocational-Technical Center, sponsored by Las Vegas Clark County School District, Las Vegas, Nevada, November 14, 1966.

New trends in education. Nevada Southern University, sponsored by Las Vegas Clark County School District, Las Vegas, Nevada, November 14, 1966.

CAI in mathematics. Valley High Schools, Southern Nevada Mathematics Council, sponsored by Las Vegas Clark County School District, November 14, 1966.

Future of computers in education. Committee for Economic Development, New York, November 17, 1966.

CAI Board Meeting of the Human Factors Society and the Society for Information Display, Palo Alto, California, December 13, 1966.

The computer in the classroom. Service Committee on Public Education, San Francisco, California, January 11, 1967.

Teaching children with computers. Walter Hays Elementary School Parent Meeting, Palo Alto, California, January 18, 1967.

On using computers to teach elementary mathematics. 38th Annual Mid-Year Education Conference, Colorado State College, Greeley, Colorado, January 27, 1967.

Where we are with the computer in our schools. Ravenswood Teachers' Association, Brentwood Elementary School, East Palo Alto, California, January 30, 1967.

The computer age. Radio of New York Worldwide, Inc., New York City, New York (radio interview), February 16, 1967.

CAI lecture and demonstration. Fifth Annual Committee on Education, Data Systems, Off. of Educ. Conf., Hotel Utah, Salt Lake City, Utah, April 11, 1967.

Computer-based instruction in elementary mathematics. State Supervisors Annual Meeting, State Supervisors of Mathematics, Las Vegas, Nevada, April 17, 1967.

Mathematics and stimulus response theories of learning. Speaker, General Session, National Council of Teachers of Mathematics, Las Vegas, Nevada, April 20, 1967.

Individualizing arithmetic instruction by using computers. Seminar, National Council of Teachers of Mathematics, Las Vegas, Nevada, April 20, 1967.

Current and future applications of computers in education. Association for Computing Machinery, Palo Alto, California, May 4, 1967.

Computer-assisted instruction. Colloquium, Department of Computer Science, Stanford, California, May 23, 1967.

CAI -- current and future. National Society for Information Display, Jack Tar Hotel, San Francisco, California, May 24, 1967.

On-line computer instruction. Commonwealth Club, San Francisco, California, June 20, 1967.

Education for what. Keynote Speaker, Annual Meeting of Mt. Diablo Unified School District, Concord, California, August 31, 1967.

H. A. Wilson

Systems for computer-aided instruction and experimentation. Annual meeting of the American Psychological Association, Washington, D.C., September 2, 1967.

Problems and prospects of computer-assisted instruction. Institute for Computer-assisted Instruction, Swampscott, Massachusetts, November 13-15, 1967.

The Stanford-Brentwood CAI Project. Canadian Council for Research in Education, Ottawa, Ontario, November 22-24, 1967.

Computers as an educational media. California Association of School Administrators Conference, panel discussion, San Francisco, California, December 7, 1967.

Appendix 4

Visitors to the Stanford-Brentwood Laboratory

January 1 - March 31, 1967

18 Associations, clubs, foundations (Ford, National Education Association, American Association of University Women)

168 Colleges and universities (presidents, administrators, professors, research specialists)

11 Consultants to education and educational research agencies

166 Corporations, companies, industrial firms (presidents, board chairmen, sales representatives, research specialists)

17 Correspondents and news media (both foreign and domestic)

12 Foreign governmental education offices and agencies

23 Governmental agencies (USOE, Bureau of Indian Affairs, PACE, Job Corps, NIH, NSF, Regional Laboratories, Military)

31 Parents, interested citizens

9 Private and parochial elementary- and secondary-school staff members

223 Public school personnel (elementary- and secondary-school superintendents, principals, teachers, consultants)

14 Publishers (presidents, executive staff members, sales representatives, editors, research specialists)

11 School board members and their committees

34 State and country education departments (superintendents, consultants, research specialists)

174 Students (elementary, secondary, and college)

915

Foreign countries represented: Belgium, Brazil, Canada, France, Finland, Hong Kong, Italy, Japan, Philippines, Switzerland, Thailand, United Kingdom, and Yugoslavia (Hawaii, Puerto Rico, Virgin Islands).

October 1 - December 31, 1967

4 Architects

9 Associations and foundations (Ford, National Education Association, American Association of University Women)

11 Consultants to educational systems and educational research agencies

97 Colleges and universities (presidents, administrators, professors, research specialists)

114 Corporations, companies, industrial firms (presidents, board chairmen, sales representatives, research specialists)

19 Correspondents, news writers, television and radio personnel (both domestic and foreign)

7 Foreign governmental agencies and education offices

15 Governmental agencies (USOE, Bureau of Indian Affairs, PACE, Job Corps, NIH, NSF, Regional Laboratories, Military--Annapolis, West Point, Air Force Academy, NASA)

117 Parents, interested citizens (100 in special demonstrations)

5 Private and parochial elementary- and secondary-school staff members

2 Public school board members and/or their committees

158 Public school personnel (elementary- and secondary-school superintendents, principals, teachers, consultants, curriculum coordinators, special education teachers)

21 Publishers (presidents, senior vice-presidents, vice-presidents, curriculum specialists, sales representatives, editors, research specialists, executive staff members)

7 State and country departments of education (superintendents, consultants, research specialists, curriculum coordinators)

156 Students (secondary, college, graduate, student teachers)

742

Foreign countries represented: Argentina, Australia, Belgium, Brazil, Canada, Chile, Colombia, England, France, Germany, Holland, Ireland, Japan, New Zealand, Norway, Philippines, Republic of South Africa, Sweden, and Uruguay.

Filming groups present: KQED-TV "Education in Motion" Series; KQED-TV "Do You Read Me?" Series; IBM Documentary Team; Information Management Facilities, Inc., for IBM.

January 1 - March 31, 1968

10 Architects

80 Colleges and universities (presidents, administrators, professors, research specialists)

141 Corporations, companies, industrial firms (presidents, board members, sales representative, research specialists)

7 Correspondents, news writers, television personnel (both domestic and foreign)

5 Foreign governmental agencies and education offices

27 Governmental agencies (USOE, PACE, Job Corps, Military, NIH)

77 Interested citizens

12 Private and parochial elementary- and secondary-school staff members

9 Public school board members and/or their committees

172 Public school personnel (elementary- and secondary-school superintendents, principals, teachers, consultants, curriculum coordinators, special education teachers, directors of special projects)

18 Publishers (vice-presidents, curriculum specialists, sales representatives, editors, executive staff members)

10 State, county and provincial departments of education

194 Students (college, university, student teachers)

762

Foreign countries represented: Argentina, Brazil, Canada, Alberta, British Columbia, Ontario, Quebec, Saskatchewan, Chile, Czechoslovakia, France, Germany, Guam, Hawaii, India, Italy, Japan, Malawi, New Zealand, Nigeria, Okinawa, Philippines, Puerto Rico, Switzerland, Sweden, Taiwan, Union of Soviet Socialists Republic, and Uruguay.

Film groups present: ASPEKT Film AB (Swedish Television), Stockholm, Sweden; Davidson Film Company, San Francisco; Encyclopedia Brittanica Films, Inc.